

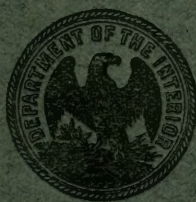
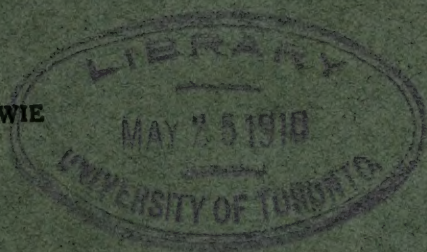
DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

OIL-STORAGE TANKS AND RESERVOIRS

WITH A BRIEF DISCUSSION OF LOSSES OF OIL
IN STORAGE AND METHODS OF PREVENTION

BY

C. P. BOWIE



WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

111

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES

VAN. H. MANNING, DIRECTOR

OIL-STORAGE TANKS AND RESERVOIRS

WITH A BRIEF DISCUSSION OF LOSSES OF OIL
IN STORAGE AND METHODS OF PREVENTION

BY

C. P. BOWIE



WASHINGTON
GOVERNMENT PRINTING OFFICE

• 1918

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines*. His office is entirely separate and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
*Government Printing Office,
Washington, D. C.*

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The cost of this publication is 25 cents.

First edition. January, 1918.



CONTENTS.

	Page.
Introduction.....	3
Tank farms.....	3
Sizes of steel tanks.....	4
Tank grades.....	4
Tank specifications.....	5
Discussion of tank specifications.....	14
Sand-line construction.....	14
Tank roofs.....	15
Size of plates.....	16
Swing pipes.....	16
Swivel joints for swing pipes.....	17
Stairways.....	17
Explosion doors.....	17
Vacuum relief valves.....	19
Tanks with wooden roofs.....	19
Cost of tanks.....	20
Concrete reservoirs.....	20
Specifications for concrete reservoirs.....	20
General details regarding reservoir construction.....	29
Choice of site for reservoir.....	29
Building embankment.....	29
Outside slope.....	30
Roof.....	30
Concrete lining.....	30
Expansion joints.....	31
Temperature variations.....	32
Effect of oil on concrete.....	32
Cost of reservoirs.....	35
Life of reservoirs and steel tanks.....	36
Losses in storage.....	37
By seepage.....	37
Losses by evaporation.....	37
Difficulties in obtaining reliable data regarding evaporation losses.....	51
Devices used for lessening evaporation losses.....	51
Water-seal tops.....	52
Sprinkling tanks with water.....	53
Gasometers.....	54
Tile-encased tanks.....	54
Burying tanks.....	54
Concrete tanks.....	54
Painting tanks light colors.....	58

	Page.
Computing volume of tanks and reservoirs and preparing gage tables.....	59
Methods of obtaining field data regarding tanks.....	59
Methods of measuring.....	61
Meaning of terms.....	62
Height of tank.....	62
Horizontal segment.....	62
Thickness of sheets.....	62
Deadwood.....	62
Manhole.....	63
Corrugated-iron and wooden tanks.....	63
Computing gage tables for tanks.....	63
Reservoir measurement and tables.....	64
Testing gage plate.....	64
Necessary measurements in testing gage plate.....	64
Computing gage table.....	65
Depreciation of oil in storage.....	65
Résumé.....	69
Acknowledgments.....	70
Publications on petroleum technology.....	71

T A B L E S .

TABLE 1. Permissible variations of plates ordered to weight.....	12
2. Permissible overweights of plates ordered to thickness.....	13
3. Temperatures without and at various points within K. T. & O. Reservoir No. 2, Bakersfield, Cal.....	32
4. Loss of oil by evaporation from 13 tanks in California.....	42
5. Summary of losses of oil in storage by evaporation.....	50
6. Results of comparative 30-day tests for losses in plain-top and water- top tanks protected with sheathing.....	53
7. Results of comparative distillation tests of fresh and of stored crudes..	66
8. Results of comparative tests of fresh and of stored California crude..	69

ILLUSTRATIONS.

PLATE I. A, Part of a tank farm under construction; B, Method of setting grade stakes for finishing tank grade to true level; C, Tank bottom in course of construction.....	4
II. Details of a 55,000-barrel 6-ring steel tank.....	6
III. Steel roof and supports for a 55,000-barrel tank.....	8
IV. Eighteen-inch swing pipe.....	10
V. Double-swivel joint for 18-inch swing pipe.....	10
VI. Standard steel stairs for 30-foot tank.....	14
VII. Details of explosion hatch for tank roof.....	14
VIII. Geared winch and cable guide for swing-pipe cable.....	16
IX. A, All-steel stairway for oil tank; B, Gasometer; C, Tile-encased tank.....	18

	Page.
PLATE X. <i>A</i> , Expansion door and vacuum relief valve; <i>B</i> , "Sheep's foot" type of roller; <i>C</i> , Wetting down loose material in tank bed.....	18
XI. Plan and vertical section of concrete-lined reservoir, capacity 750,000 barrels.....	22
XII. Details of sump and swing pipe for 750,000-barrel concrete-lined reservoir.....	24
XIII. Details of roof framing and concrete lining of 750,000-barrel reservoir.....	26
XIV. Details of roofing for 750,000-barrel concrete-lined reservoir.....	28
XV. Arrangement of reinforcing material for concrete-lined reservoir, capacity 750,000 barrels.....	28
XVI. <i>A</i> , Trimming slope by hand; <i>B</i> , Trimming slope with special scraper.....	30
XVII. <i>A</i> , Oiling the completed embankment; <i>B</i> , Incompleted tank, roof construction begun and reinforcing material in place; <i>C</i> , Excavating for joint between floor and side of concrete lining.....	30
XVIII. <i>A</i> , Lifting roof support into position; <i>B</i> , Sheathed roof ready for roofing paper.....	32
XIX. <i>A</i> , Oil-storage tank with water-seal top; <i>B</i> , Sprinkler for cooling tank; <i>C</i> , Baffle plate around edge of roof to deflect water from sprinkler against side of tank.....	52
XX. Detail of tile casing for 55,000-barrel tank.....	54
XXI. <i>A</i> , Excavating for concrete-lined oil tank; <i>B</i> , Forms for concrete tank; <i>C</i> , Completed tank.....	56

TANK FARM.

Storage facilities, whether steel tanks or reservoirs, are grouped together in what are known as "storage farms," some of which in the United States already have capacities as great as 75,000,000 barrels. The ideal site for a farm is on ground that is comparatively level. Tanks, which are usually 100,000 to 500,000 barrel capacity, are placed about 50 feet apart in rows, leaving the aisles about 100 feet wide. Each tank is then surrounded by a low wall, about 10 feet high, to hold the contents of the tank as shown on Plate I, A. In many instances these rows are circular and are themselves enclosed by a system of rectangular levees, built continuously between tanks, and dividing the whole farm into a system of deep bermed squares, the tanks being at the centers of the squares. Should any one tank catch fire it is thus isolated from its neighbors, and even if it is a large one, and its entire contents are consumed, if the levees are properly constructed it will do so without endangering the other tanks. In certain large reservoirs of similar type, however, the

OIL-STORAGE TANKS AND RESERVOIRS, WITH A BRIEF DISCUSSION OF LOSSES OF OIL IN STORAGE AND METHODS OF PREVENTION.

By C. P. BOWIE.

INTRODUCTION.

The Bureau of Mines has been conducting investigations with the view of determining the types of containers best adapted to the storage of oil. These investigations have shown that tanks composed wholly of steel give the best results. Where larger containers than it is feasible to build with steel are desired, concrete-lined reservoirs can be recommended for some grades of oil. Practically all such containers in use at present have wooden roofs and this type of construction is here described, although it is the belief of the writer that concrete roofs would be far more satisfactory in every way, and that the difference in cost between a concrete and a wooden roof would, as a rule, in a few years' time, be offset by a saving of oil and in cost of repairs and renewals.

TANK FARMS.

Storage facilities, whether steel tanks or reservoirs, are grouped together in what are known as "storage farms," some of which in the United States already have capacities in excess of 24,000,000 barrels. The ideal site for a farm is on ground that is comparatively level. Tanks, which are usually of 37,000 to 55,000 barrel capacity, are placed about 500 feet center to center, making the distance shell to shell about 400 feet. Each tank is then surrounded by a levee of sufficient height to hold the entire content of the tank, as shown on Plate I, A. In many instances these levees are circular and are themselves inclosed by a system of rectangular levees, built equidistantly between tanks, and dividing the whole farm into a system of checkerboard squares, the tanks being at the centers of the squares. Should any one tank catch fire it is thus isolated from its neighbors, and even though it may burn until its entire contents are consumed, if the levees are properly constructed it will do so without undue menace to the other tanks. As regards large reservoirs of 500,000 to 1,000,000 barrel

capacity, it is of course not practical to make the empounding area of a surrounding levee of sufficient size to hold the entire contents of the reservoir. Nevertheless, levees between reservoirs are advisable, and it is the practice to provide them. Levees are to be discussed more fully in a subsequent publication on fire protection to be issued by the Bureau of Mines.

SIZES OF STEEL TANKS.

Steel tanks for the storage of oil are manufactured in various sizes up to 55,000-barrel capacity. These have a diameter of 114 feet 6 inches and are 30 feet high. The usual size is the 55,000-barrel tank, although the Standard Oil Co., especially, is using great numbers of 37,000-barrel tanks. Tanks may be erected by contract or by the owners. However, for various reasons, the contract method is generally preferable. Under this method the company furnishes the grades on which the tanks are placed, and transportation of men and materials from the nearest railroad station; the contractors furnish the material, the railroad transportation, and all labor for erection.

TANK GRADES.

As to tank grades, it is well to note in passing that too much care can not be exercised in their preparation. They should be either all in fill or all in excavation and carefully graded to a true level surface. Plate I, *B*, shows the method of setting grade stakes. A tank built partly on filled ground and partly on excavated ground is in constant danger of being disrupted at the point where the foundation goes from cut to fill, as the filled part of the foundation will settle, whereas the part in cut ground probably will not, or at least not to so great a degree. Where it is necessary to build up a grade, the best policy is to fill the entire area to approximately the same depth, so as to insure as uniform settling as possible. It is good practice, also, unless the length of haul is excessive, to use the Fresno type of grader and to distribute the dirt in thin layers, allowing the stock to pass back and forth over the loose material as often as feasible. Puddling the grade in filled ground is also good practice.

As the bottom of the tank is composed of relatively thin plates, every precaution should be taken to prevent its deterioration from the corrosive action of alkaline salts contained in the soil upon which it rests, and also from similar chemical action by reason of water leaking through an imperfect seam and forming a puddle beneath the plates.

To eliminate as far as possible the detrimental effect of soil corrosion, several inches of oil sand is usually placed on the surface of the completed grade, or if this is impracticable, the completed surface is oiled, and the oil worked in 3 to 4 inches by rakes. The tank bot-



A. PART OF A TANK FARM UNDER CONSTRUCTION.



B. METHOD OF SETTING GRADE STAKES FOR FINISHING TANK GRADE TO TRUE LEVEL.



C. TANK BOTTOM IN COURSE OF CONSTRUCTION.

tom is thoroughly coated with a good quality of asphaltic or other rust-resisting paint before being lowered onto the grade. Plate I, C, shows a tank bottom in course of construction.

TANK SPECIFICATIONS.

Perhaps no better description of a steel tank can be given than that furnished by a recital of the specifications covering its erection and the material of which it is composed. Following are such specifications for a tank of 55,000-barrel capacity, of steel construction throughout, and of a type known to the trade as "gas-tight." This capacity of tank is considered to be the largest practicable for fabrication and construction in the field, and the type of steel tank best adapted to the storage of petroleum products so far as regards fire hazards and losses by seepage and evaporation.

SPECIFICATIONS FOR 55,000-BARREL ^a STEEL TANK WITH STEEL ROOF.

The ———, in itself or by its duly authorized representative, shall be referred to in these specifications as the "Company."

The firm undertaking to furnish and erect the tank herein described, in itself or by its duly authorized representative, shall be referred to in these specifications as the "Contractor."

At all times during the progress of the fabrication of the tank material or erection of the tank, the Contractor shall designate some person as his representative, to whom instructions may be given by a duly authorized representative of the Company.

(1) *Location*.—Tank to be erected upon foundation prepared by the Company.

(2) *Freight and hauling*.—The Contractor shall deliver all tank material, tools, and appliances f. o. b. cars nearest railroad station. The Company shall haul all tank material, tools, and appliances necessary for the construction of the tank from the railroad station, and shall deliver same within 100 feet of the tank site, and on completion of the work shall return tools and appliances to the railroad station.

(3) *Drawings*.—The following drawings form an integral part of and are to be used in conjunction with these specifications: Plates II, III, IV, V, VI, VII, and VIII.

(4) *Dimensions*.—Diameter, 114 feet 6 inches, average inside measurement; height, 30 feet.

(5) *Material*.—All material for the tank shall be of steel, complying with Standard Specifications for Structural Steel of the American Society for Testing Materials (copy of which is hereto attached). Contractor to furnish a certificate from an approved firm of testing engineers covering all materials used, but such certificate shall not act to prevent Company exercising the right to reject undergaged plates or defective material wherever it may be found.

Tank to be composed of 6 rings of equal height, as shown on Plate II. Plates to be of uniform size with minimum dimensions, as hereinafter designated.

All plates shall be ordered to gage, permissible variations to be in accord with specifications for structural steel above referred to.

(6) *Punching and riveting, etc.*—Plates and angles for the shell of the tank must be rolled to proper curvature.

Plates and angles must be punched from the sides that are to be in contact, and the punching must be so accurate that the holes will match within 10 per cent of their diameter when plates are assembled. Holes for hot rivets shall be punched

^a 42-gallon barrels.

not more than one-sixteenth of an inch larger in diameter than the rivets that are to fill them.

Riveting shall be done with pneumatic tools, an air pressure of approximately 90 pounds per square inch at the receiver being used. Rivets must conform with the specifications in diameter, length, pitch, and marginal distance. Should any burned, deformed, or loose rivets be found in the work, they are to be cut out and replaced. No calking of rivets will be allowed. Riveting of the bottom sheets shall be done from the inside; all other riveting, including riveting of the bottom to the bottom angle, and of the roof, shall be done from the outside. All rivets one-half inch in diameter or larger shall be driven hot.

(7) *Calking*.—All edges to be calked shall be beveled by planing. All seams must be thoroughly calked with a round-nosed pneumatic calking tool. The shell of the tank shall be formed by ascending inside courses calked on the outside. Bottom plates to be calked on the inside except at angle iron, where they are to be calked on the outside, and both legs of angle iron shall be calked inside. Angle irons to be butt calked at joints.

All roof plates to be calked from the outside of tank, this to include also calking at top angle iron.

All castings, nozzles, flanges, and manheads riveted to the tank must be calked thoroughly inside and outside.

(8) *Testing the bottom*.—Upon completion of the bottom and the first ring of the shell, and before the bottom has been lowered to the ground, the bottom shall be covered with water to a depth of not less than 5 inches, and all leaks that develop shall be made tight to the satisfaction of the Company or its duly authorized representative before any lowering is done. Necessary water for the testing shall be furnished by the Company for one test only. Should additional tests be made, water will be charged to the contractor at cost.

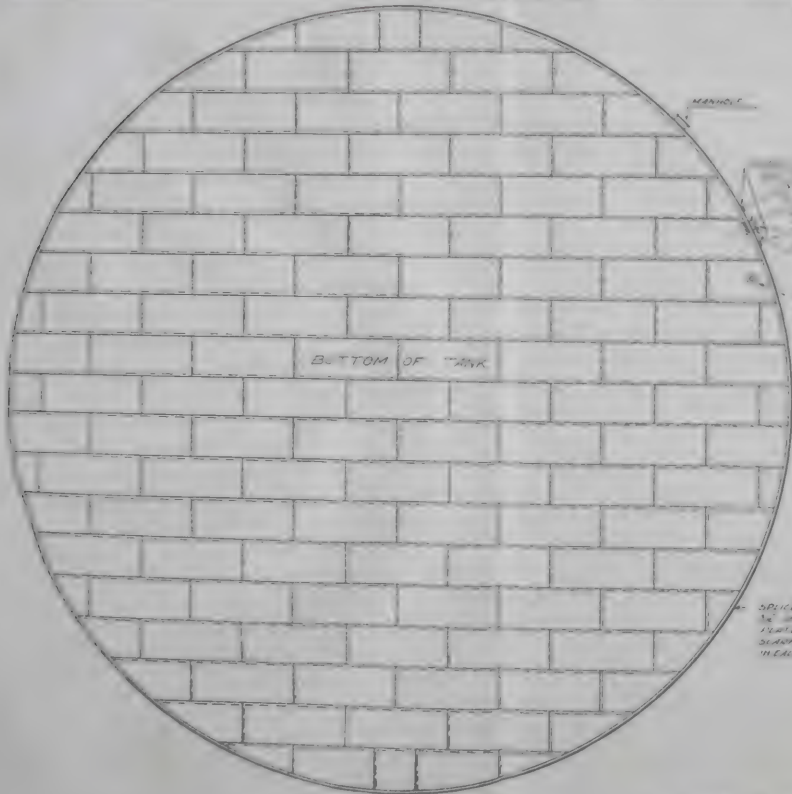
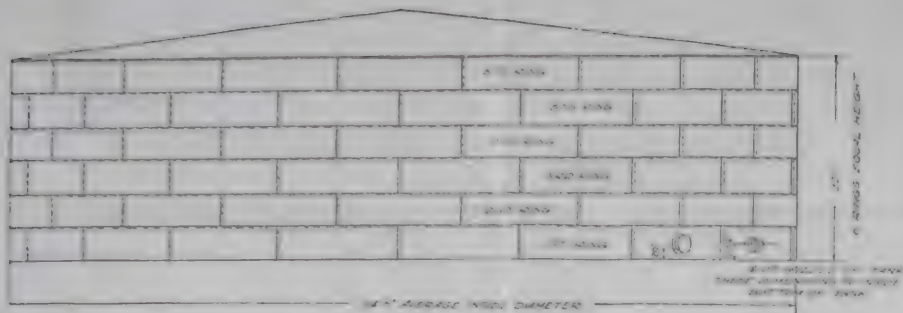
(9) *Thickness of metal, spacing of rivets, etc.*—The thickness of metal, the spacing of rivets, and the like, shall be as set forth in the following table:

Thickness of metal, spacing of rivets, etc., prescribed for tank covered by these specifications.

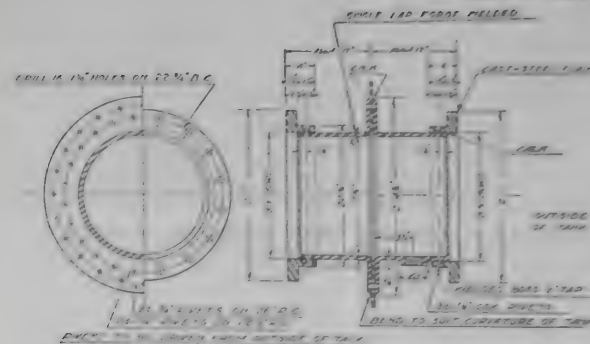
Part.	Thick- ness.	Weight per square foot.	Horizontal rivet- ing—all single rows.		Vertical riveting.			
			Diam- eter of rivets.	Pitch.	Rows.	Diam- eter of rivets.	Pitch.	Distance between rows, center to center.
	Inches.	Pounds.	Inches.	Inches.		Inches.	Inches.	Inches.
Bottom sketch plates.....	$\frac{1}{8}$	12.75	1	$1\frac{1}{2}$				
Bottom rectangular plates....	$\frac{1}{4}$	10.20		$1\frac{1}{2}$				
First ring.....	$\frac{1}{8}$	22.95		$2\frac{1}{2}$	Triple..		3	2
Second ring.....	$\frac{1}{8}$	20.40		$2\frac{1}{2}$	..do....		3	2
Third ring.....	$\frac{3}{16}$	16.58		$2\frac{1}{2}$	Double..		$2\frac{1}{2}$	2
Fourth ring.....	$\frac{1}{8}$	12.75		$2\frac{1}{2}$	..do....		$2\frac{1}{2}$	$1\frac{1}{2}$
Fifth ring.....	$\frac{1}{8}$	10.20		2	..do....		$2\frac{1}{2}$	$1\frac{1}{2}$
Sixth ring.....	$\frac{1}{4}$	10.20		2	..do....		$2\frac{1}{2}$	$1\frac{1}{2}$
Roof plates.....	$\frac{1}{8}$	7.65		$1\frac{1}{2}$				

(10) *Size of plates and angles*.—Plates for shell shall be 60 by 180 inches center to center of rivet laps (24 plates per ring). Bottom and top rectangular plates shall be 60 by 180 inches center to center of rivet laps. Bottom angle irons connecting the bottom and the shell shall be 4 by 4 inches by $\frac{5}{8}$ inch. Top angle iron connecting the roof with the shell shall be 3 by 3 inches by $\frac{3}{8}$ inch.

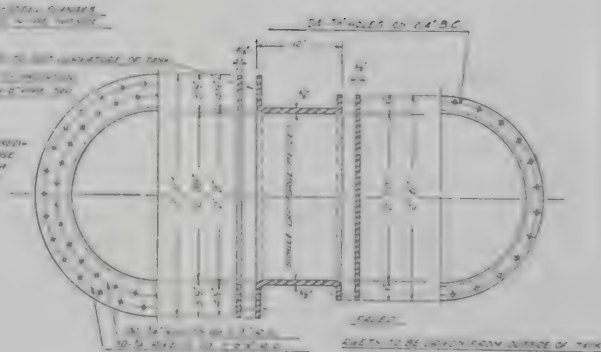
(11) *Angle shoes*.—Shoes uniting ends of angles shall be made of $\frac{3}{8}$ -inch 16-pound steel, and shall be not less than 12 inches in length with the ends drawn to a thin edge.



SPlice BOTTOM ANGLE WITH
1/4" WELD DETACHED ANGLE &
PLATED. SHIP TO BE FULL
CLEANED & TO TRAIL 6 WELDS
IN EACH 1/4" 1/4" ANGLE



NOZZLE
1 PLATED COMPLETE WITH 1/4" WELD TAP
1 PLATED COMPLETE WITHOUT 1/4" WELD TAP



MANHOLE
1 PLATED - COMPLETE

MANHOLES-NOZZLES-FLANGES
TO BE LOCKED WELDED



Shoes must be set between steel angles, shell and bottom of tank, and must be of sufficient width to be properly calked outside the line of the steel angles.

(12) *Shell*.—The shell shall be composed of 6 courses, as shown on Plate II, each course to be a true circle and to be free from flaws and buckles. The first two courses, counting from the bottom upward, are to have the vertical seams triple riveted. The third, fourth, and fifth courses are to have the vertical seams double riveted. All horizontal seams are to be single riveted.

(13) *Roof*.—Roof to be composed of $\frac{3}{8}$ -inch steel plates weighing 7.65 pounds per square foot, and to rest on steel roof supports as shown on Plate III. The roof, however, shall not be riveted to roof supports at any point. When complete the roof must be "gas tight," and shall show no leaks when tested with an air pressure equal to the weight of the roof.

(14) *Roof supports*.—Roof supports shall be constructed of steel shapes as shown on Plate III. Size and fabrication to conform to those shown, and workmanship to be approved by the Company.

(15) *Manholes*.—Two manholes shall be placed in the first course of tank, as designated by the Company in the field. Each manhole shall be 20 inches deep, and shall be made of steel with welded seam, weighing not less than 21 pounds per square foot. Neck of flange must be covered to suit radius of tank shell. The manhole shall be fitted with steel cover plate five-eighths inch thick, faced and punched to suit holes in flange, and bolted to flange with 24 $\frac{3}{4}$ -inch square-head bolts and hexagon nuts. The manhole shall be riveted to tank shell with $\frac{3}{4}$ -inch rivets, as shown on Plate II.

(16) *Pipe flanges, nozzles, etc.*—The tank shall be furnished with the following pressed-steel flanges secured to the shell with $\frac{3}{4}$ -inch diameter rivets. Position to be designated in field by the Company. One pair of flanges to be threaded for 8-inch pipe for drawing off water. One pair of flanges to be threaded for 8-inch pipe for oil-inlet pipe. Bottom of tank to be fitted with one single flange threaded for 8-inch pipe, secured to bottom of tank with $\frac{1}{2}$ -inch rivets, location to be designated in the field by the Company. Roof of tank to be fitted with two 8-inch and one 4-inch pressed-steel flanges located in field by the Company, also with manholes and gage hatch, as shown in detail on Plate III.

Tank to be fitted with one combined swing pipe and suction nozzle, as shown in detail on Plate II. Nozzle to be made of single-lap forge-welded steel plate $\frac{1}{2}$ inch thick, and to be secured to shell of tank in position located in the field by the Company, with a double row of $\frac{3}{4}$ -inch rivets, as shown on drawing. Swing pipe and suction end of nozzle to be fitted with cast-steel flange, as shown.

(17) *Swing pipe*.—Contractor shall supply and install swing pipe as shown in detail on Plate IV. Swing pipe to be delivered on the job so that it may be placed (but not installed) inside of the tank shell as soon as the bottom is tested and lowered. Contractor will not be permitted to lift the swing pipe over the shell of the tank after more than the first ring of the tank is in position.

(18) *Double-swivel joint for swing pipe*.—Contractor shall supply and install to the satisfaction of the Company a double-swivel elbow joint for connecting the swing pipe to the swing-pipe nozzle. Details for this swivel joint are shown on Plate V. Construction of joint must follow closely details as per drawing.

(19) *Stairway*.—The Contractor shall furnish and install a stairway anchored to the shell of the tank and running from the ground to the top of the tank, as shown on Plate VI. This stairway shall be equipped with door covered with No. 12 wire screen, $\frac{1}{2}$ -inch mesh, as shown on Plate VI.

(20) *Explosion hatches*.—The tank shall be equipped with eight explosion hatches to be located on roof of tank in field as designated by the Company. Details of explosion hatches are shown on Plate VII. These explosion hatches are to be furnished by Contractor and must conform closely to drawing. Brass rods must be true and

smoothly turned, and must be accurately fitted in babbitted bearings, as shown, in order that aluminum cover of hatch will rise without binding.

(21) *Cable guides and stuffing box.*—Tank shall be provided with cable guides and stuffing box for cable, as shown in detail on Plate VIII. One hundred feet of $\frac{1}{2}$ -inch diameter 6-strand 19-wire plow-steel galvanized-wire cable shall be furnished by Contractor. Sheave wheels for cable must be accurately centered and supports securely riveted to tank shell and calked inside and outside of tank.

(22) *Swing-pipe winch.*—Swing-pipe winch shall be furnished by Contractor as per detail shown on Plate VIII, and shall be placed in position by Contractor where designated by the Company.

(23) *Painting.*—The outside of the tank, including the top, shall be painted with one coat of asphaltic, graphite, or other paint approved by the Company, to be spread on with brush and to thoroughly cover the metal. The bottom of the tank shall be painted with three coats of the same paint, at least 6 hours being allowed for each successive coat to dry.

(24) *Inspection.*—All material and workmanship shall be subject at all times to the inspection of the Company or its duly authorized representative, and any defective material, whether discovered before or after it has been used in the work, shall be replaced in the construction by the Contractor at his own expense. Contractor shall also furnish transportation from railroad to tank site for such new material.

(25) *Final test.*—Upon the completion of the tank, and before it is inspected, it may be filled with oil or water at the option and expense of the Company, and any leaks that develop shall be made tight to the satisfaction of the Company by the Contractor at his own expense.

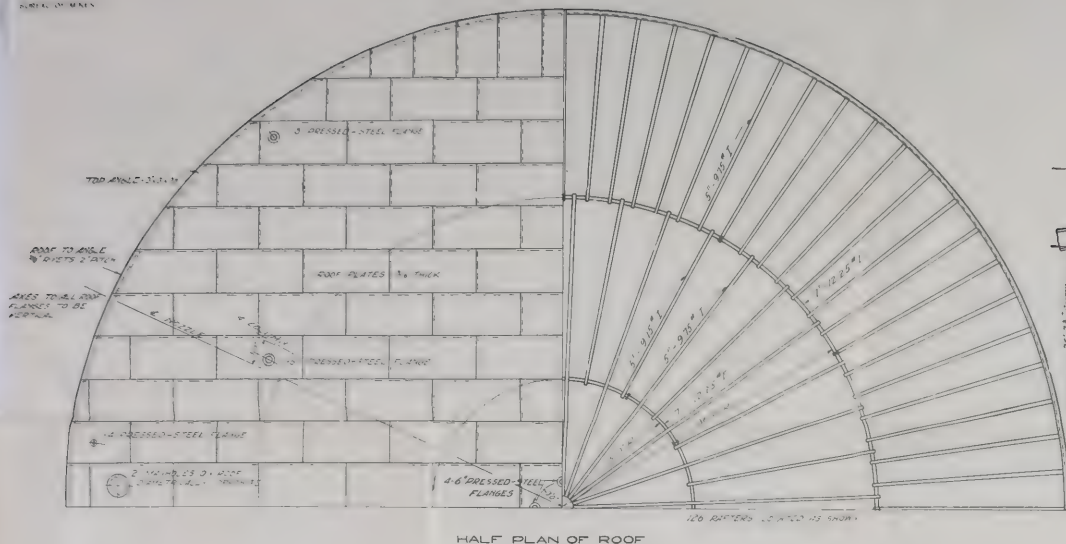
(26) *Boarding of work crew.*—The Contractor shall provide board, lodging, and transportation for his men at all times. Commissary water will be furnished by the Company. Purifying of same, where necessary, to be done by the Contractor. No intoxicating liquors shall be permitted on the premises.

(27) *Workmanship.*—The work throughout shall be done in a first-class workman-like manner, and only men competent in their line shall be employed about the work. Upon demand of the Company, or its duly authorized representative, any workman who in the judgment of the Company is found to be incompetent, careless, or intemperate shall be dismissed.

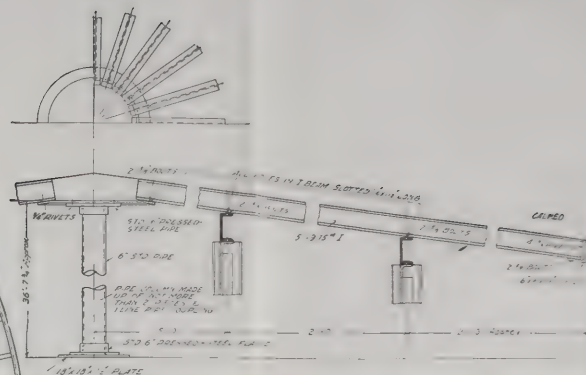
(28) *Extra work.*—These plans and specifications are intended to describe a complete oil-tight and gas-tight tank. Any work and material necessary to produce such a tank, although not mentioned in the specifications or shown on the plans, shall be supplied by the Contractor without extra cost to the Company. The Company will not pay for extra work unless it has been executed on a written order by the Company, or its duly authorized representative.

(29) *Rubbish.*—On completion of the work all useless material used in the construction shall be cleared away from inside and outside the tank, and shall be removed to such a point upon the premises as may be designated by the Company.

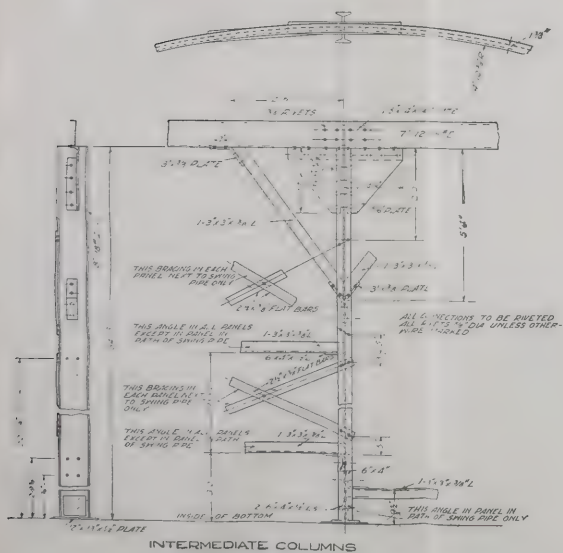
(30) *Camp sanitation.*—The Contractor shall at all times maintain his boarding house, sleeping quarters, and all other appurtenant facilities in a sanitary condition to the satisfaction of the Company.



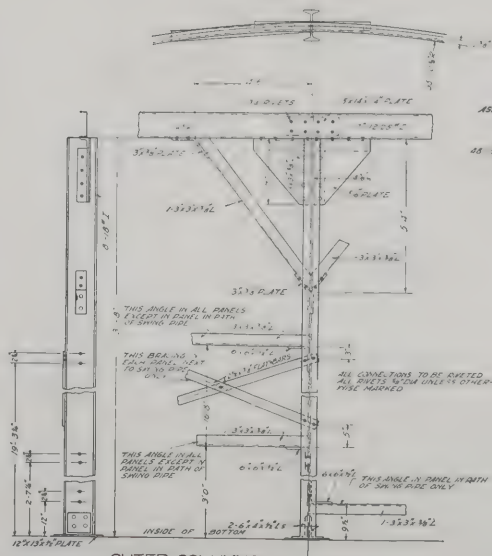
HALF PLAN OF ROOF



HALF SECTION THROUGH C OF ROOF

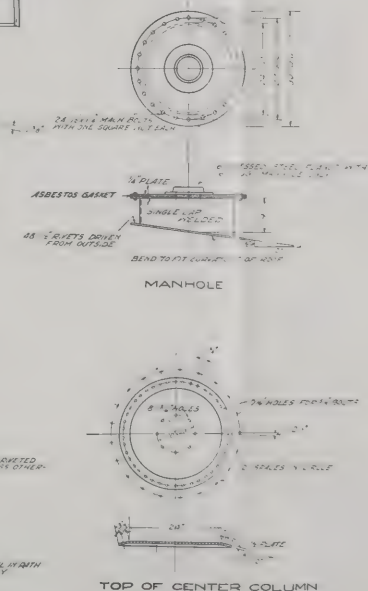


INTERMEDIATE COLUMNS



OUTER COLUMNS

STEEL ROOF AND SUPPORTS FOR A 55,000-BARREL TANK.



TOP OF CENTER COLUMN

AMERICAN SOCIETY FOR TESTING MATERIALS.

Philadelphia, Pa., U. S. A.

Affiliated with the

International Association for Testing Materials.

STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR BUILDINGS.

Serial designation: A 9-16.

Adopted 1901; revised 1909, 1913, 1914, 1916.

I. MANUFACTURE.

Process.

1. (a) Structural steel, except as noted in paragraph b, may be made by the Bessemer or the open-hearth process.

(b) Rivet steel, and steel for plates or angles over $\frac{3}{4}$ inch in thickness which are to be punched, shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical composition.

2. The steel shall conform to the following requirements as to chemical composition:

	Structural steel.	Rivet steel.
Phosphorus { Bessemer.....	Not over 0.10 per cent.	
Open-hearth.....	Not over 0.06 per cent.	Not over 0.06 per cent.
Sulphur.....		Not over 0.045 per cent.

Ladle analyses.

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in section 2.

Check analyses.

4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension tests.

5. (a) The material shall conform to the following requirements as to tensile properties:

Properties considered.	Structural steel.	Rivet steel.
Tensile strength, pounds per square inch.....	55,000 to 65,000.....	46,000 to 56,000.
Yield point, minimum, pounds per square inch.	0.5 tensile strength.....	0.5 tensile strength.
Elongation in 8 inches, minimum, per cent....	1,400,000	1,400,000
Elongation in 2 inches, minimum, per cent....	Tensile strength ^a	Tensile strength
	22.....	.....

^a See section 6.

(b) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in elongation.

6. (a) For structural steel over $\frac{3}{4}$ inch in thickness, a deduction of 1 from the percentage of elongation in 8 inches specified in section 5, *a*, shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, to a minimum of 18 per cent.

(b) For structural steel under $\frac{5}{16}$ inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in section 5, *a*, shall be made for each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch.

Bend tests.

7. (a) The test specimen for plates, shapes, and bars, except as specified in paragraphs *b* and *c*, shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ inch or under in thickness, flat on itself; for material over $\frac{3}{4}$ inch to and including $1\frac{1}{4}$ inches in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(b) The test specimen for pins, rollers, and other bars, when prepared as specified in section 8, *c*, shall bend cold through 180 degrees around a 1-inch pin without cracking on the outside of the bent portion.

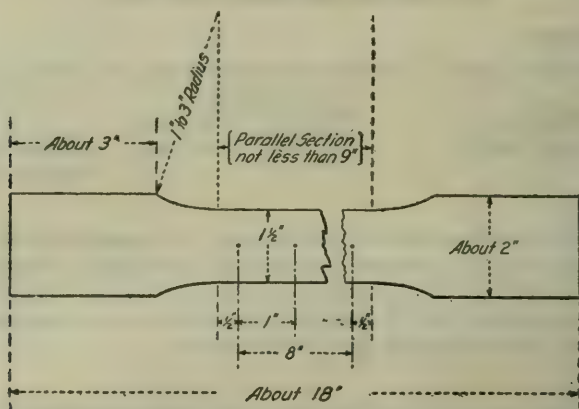


FIGURE 1.—Form and dimensions of test specimen for tension and bending tests of plates, shapes, and bars.

(c) The test specimen for rivet steel shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

Test specimens.

8. (a) Specimens for tension and bending tests shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in paragraph *b*.

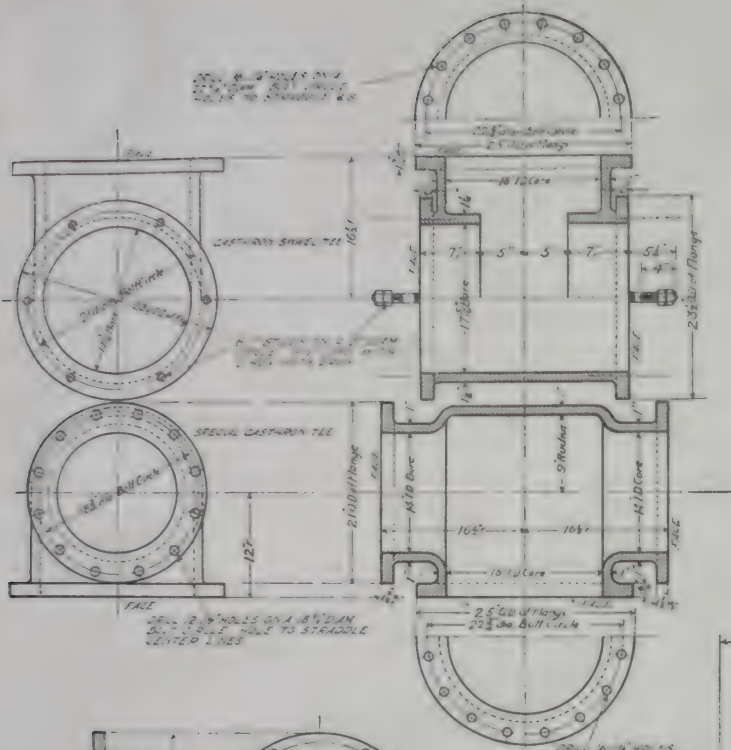
(b) Specimens for tension and bending tests of pins and rollers shall be taken from the finished bars, after annealing when annealing is specified.

(c) Specimens for tension and bending tests of plates, shapes, and bars, except as specified in paragraphs *d*, *e*, and *f*, shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in figure 1, or with both edges parallel.

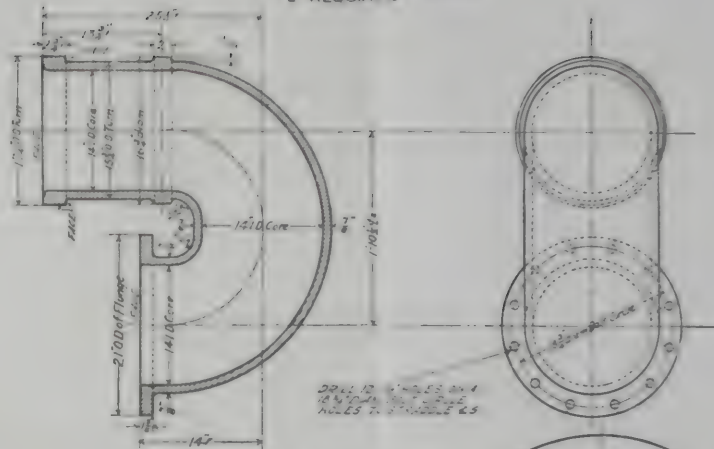
(d) Specimens for tension and bending tests of plates over $1\frac{1}{2}$ inches in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ inch for a length of at least 9 inches.

(e) Specimens for tension tests of pins, rollers, and bars more than $1\frac{1}{2}$ inches in thickness or diameter may conform to the dimensions shown in figure 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the

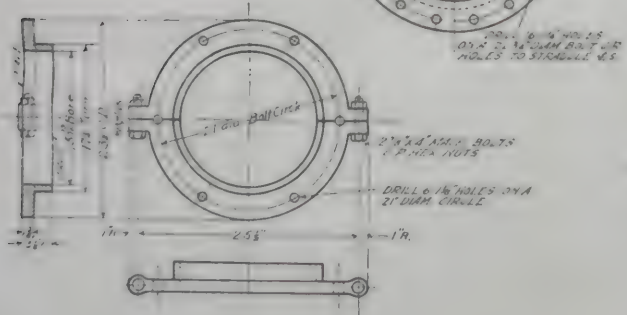




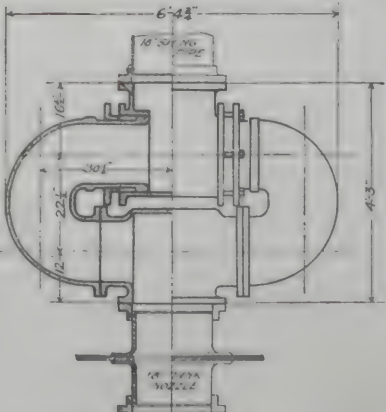
CAST-IRON RETURN ELBOW
2 REQUIRED



DRILL 12 HOLES IN 1
16" DIA. BOLT CIRCLE
HOLES TO STRADDLE C.S.



CAST-IRON SPLIT GLAND
2 REQUIRED



GENERAL ARRANGEMENT

DOUBLE-SWIVEL JOINT FOR 18-INCH SWING PIPE.

load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ inch in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

(f) Specimens for tension and bending tests of rivet steel shall be of the full-size section of bars as rolled.

Number of tests.

9. (a) One tension and one bending test shall be made of material from each melt; except that if material from one melt differs $\frac{3}{8}$ inch or more in thickness, one tension and one bending test shall be made from both the thickest and the thinnest material rolled.

(b) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension-test specimen is less than that specified in section 5, a, and any part of the fracture is more than $\frac{1}{4}$ inch from the center of the gage length of a 2-inch specimen or is outside the middle third of the gage length of an 8-inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

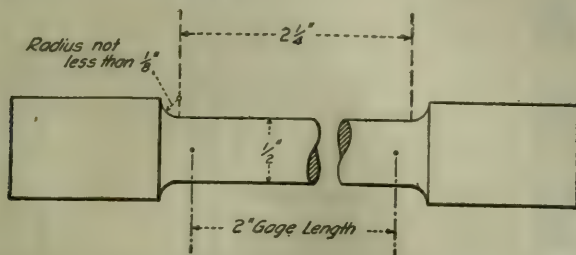


FIGURE 2.—Form and dimensions of test specimen for tension tests of pins, rollers, and bars more than $1\frac{1}{2}$ inches thick.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible variations.

10. The cross section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(a) When ordered to weight per square foot: The weight of each lot^a in each shipment shall not vary from the weight ordered more than the amount given in Table 1.

(b) When ordered to thickness: The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot^b in each shipment shall not exceed the amount given in Table 2.

^a The term "lot" applied to Table 1 means all of the plates of each group width and group weight.

^b The term "lot" applied to Table 2 means all of the plates of each group width and group thickness.

TABLE 1.—Permissible variations of plates ordered to weight.

Ordered weight.		Permissible variations in average weights per square foot of plates for widths given. (Expressed in percentages of ordered weights.)												Ordered weight.							
		Under 48 inches.		48 to 60 inches, exclusive.		60 to 72 inches, exclusive.		72 to 84 inches, exclusive.		84 to 96 inches, exclusive.		96 to 108 inches, exclusive.				108 to 120 inches, exclusive.		120 to 132 inches, exclusive.		132 inches or over.	
		Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.			Over.	Under.	Over.	Under.	Over.	Under.
<i>Pounds per square foot.</i>																					
Under 5.		5	3	5.5	3	6	3	7	3	8	3	9	3	10	3	11	3	12	3		
5 to 7.5, exclusive.		4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3	11.5	3	12.5	3		
7.5 to 10, exclusive.		4	3	5	3	6	3	7	3	8	3	9	3	10	3	11	3	12	3		
10 to 12.5, exclusive.		3.5	2.5	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3	11.5	3		
12.5 to 15, exclusive.		3	2.5	4	3	5	3	6	3	7	3	8	3	9	3	10	3	11	3		
15 to 17.5, exclusive.		2.5	2.5	3.5	3	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3		
17.5 to 20, exclusive.		2.5	2	3.5	3	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3		
20 to 25, exclusive.		2.5	2	3.5	3	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3		
25 to 30, exclusive.		2.5	2	3.5	3	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3		
30 to 40, exclusive.		2.5	2	3.5	3	4.5	3	5.5	3	6.5	3	7.5	3	8.5	3	9.5	3	10.5	3		
40 or over.		2	2	3	2	4	2	5	2	6	2	7	2	8	2	9	2	10	2		

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{2}$ times the amount given in this table.

TABLE 2.—*Permissible overweight of plates ordered to thickness.*

Ordered thickness.	Permissible excess in average weights per square foot of plates for widths given. (Expressed in percentages of nominal weights.)								Ordered thickness.
	Under 48 inches.	48 to 60 inches, exclusive.	60 to 72 inches, exclusive.	72 to 84 inches, exclusive.	84 to 96 inches, exclusive.	96 to 108 inches, exclusive.	108 to 120 inches, exclusive.	120 to 132 inches, exclusive.	132 inches or over.
<i>Inches.</i>									
Under 1/8	9	10	12	14					Under 1/8
1/8 to 1/4, exclusive.	8	9	10	12					1/8 to 1/4, exclusive.
1/4 to 3/8, exclusive.	7	8	9	10	12				1/4 to 3/8, exclusive.
3/8 to 1/2, exclusive.	6	7	8	9	10	12		16	3/8 to 1/2, exclusive.
1/2 to 3/4, exclusive.	5	6	7	8	9	10	14	14	1/2 to 3/4, exclusive.
3/4 to 1, exclusive.	4.5	5	6	7	8	9	10	12	3/4 to 1, exclusive.
1 to 1 1/4, exclusive.	4	4.5	5	6	7	8	9	10	1 to 1 1/4, exclusive.
1 1/4 to 1 1/2, exclusive.	3.5	4	4.5	5	6	7	8	9	1 1/4 to 1 1/2, exclusive.
1 1/2 to 1 3/4, exclusive.	3	3.5	4	4.5	5	6	7	8	1 1/2 to 1 3/4, exclusive.
1 3/4 to 2, exclusive.	2.5	3	3.5	4	4.5	5	6	7	1 3/4 to 2, exclusive.
2 or over.	2.5	2.5	3	3.5	4	4.5	5	6	2 or over.

V. FINISH.

Finish.

11. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

12. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. (a) Unless otherwise specified, any rejection based on tests made in accordance with section 4 shall be reported within five working days from the receipt of samples.

(b) Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer will be notified.

Rehearing.

15. Samples tested in accordance with section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

DISCUSSION OF TANK SPECIFICATIONS.

SAND-LINE CONSTRUCTION.

Although the modern steel tank of large capacity, as in use to-day, has proven itself admirably designed to withstand the pressure brought to bear upon it from within, it is, nevertheless, poorly equipped against wind stresses from without. The type of steel roof with steel supports described in the foregoing specifications is considered by many engineers to be sufficiently rigid to insure the tank against any damage from the wind. Nevertheless, although the writer has visited practically all the large oil-storage centers in the United States, and has not found a single properly constructed steel-topped tank with steel roof supports that has collapsed during a wind storm, he believes that the so-called sand-line construction for overcoming wind stresses can not be too strongly recommended, and in localities subject to wind storms should be used in all types of large steel tanks—those having steel roofs as well as those with wooden roofs on wooden roof supports.



Finish. -

11. The finished workmanlike

Marking.

12. The name stamped or marked on a small section for identification of each pin and, if practicable,

13. The instructions while work is in manufacture. The manufacturer should inform him that the All tests (except fracture price) not to interfere with

14. (a) Use with section

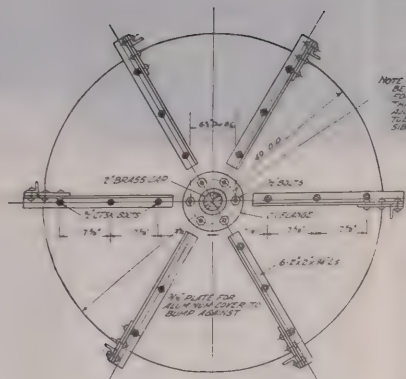
(b) Material manufactured

Rehearing.

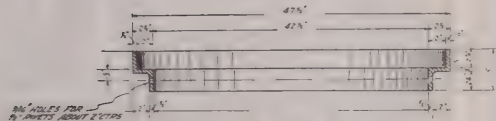
15. Samples shall be prepared for examination with the material within the

Although the writer has proposed that the equipment be considered against the writer's United States topped storm, coming localities steel to roofs of

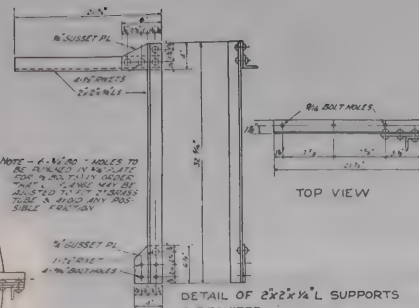




TOP VIEW OF HATCH

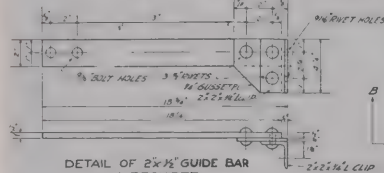


DETAIL OF CAST-STEEL TROUGH

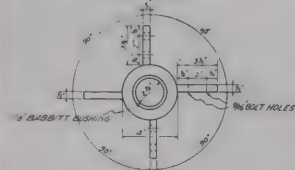
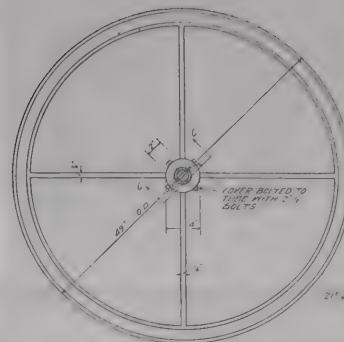


TOP VIEW

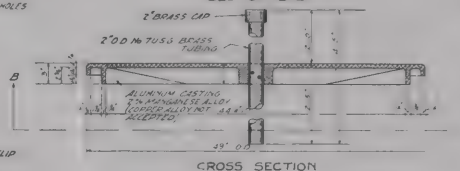
DETAIL OF 2x2x1/4\"/>



DETAIL OF 2x1/2\"/>

DETAIL OF C1 GUIDE SPIDER
1 REQUIRED

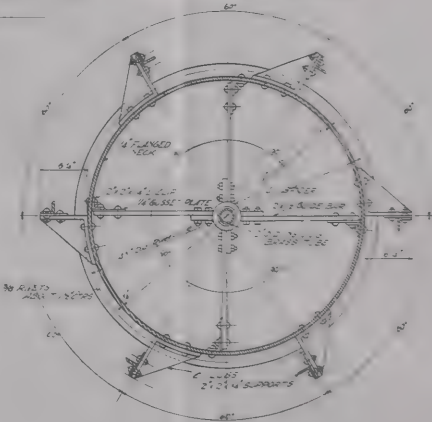
SECTION B-B



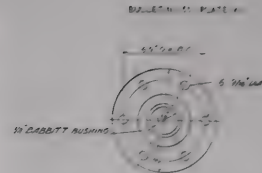
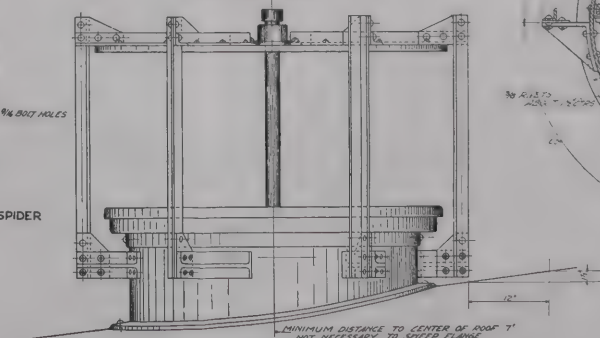
CROSS SECTION



SECTION C-C

DETAIL OF ALUMINUM COVER & TUBE
REQUIRED - COMPLETE

SECTION A

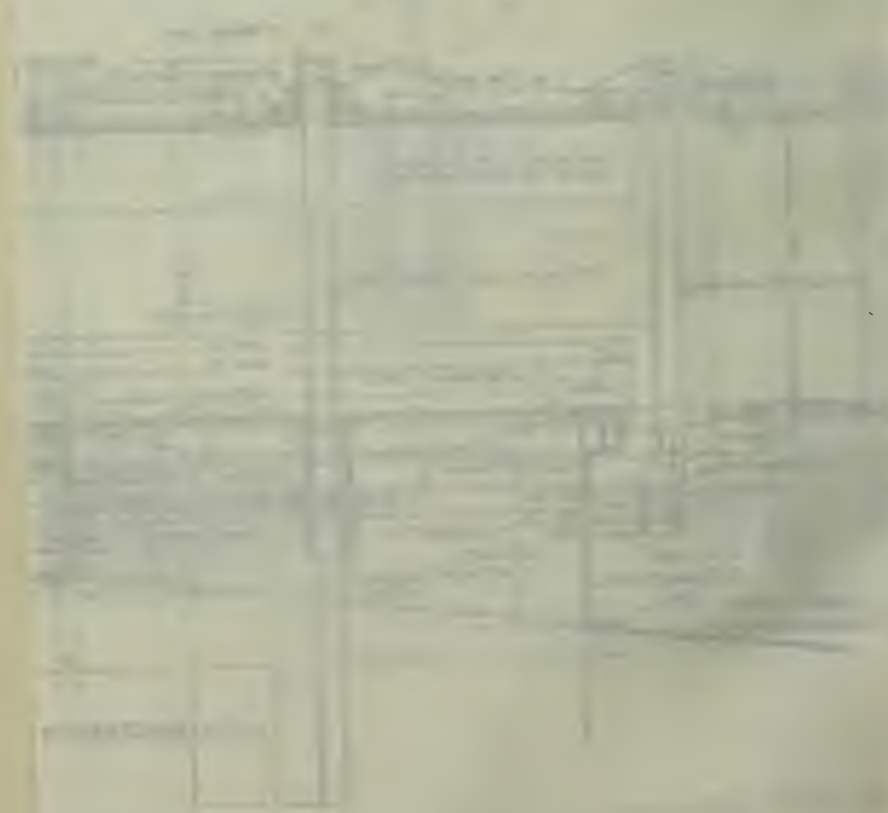
DETAIL OF C1 FLANGE
REQUIREDMINIMUM DISTANCE TO CENTER OF ROOF 7'
NOT NECESSARY TO SPIDER FLANGE

DETAILS OF EXPLOSION HATCH FOR TANK ROOF.



THE DOME

THE DOME IS A STRUCTURE OF
WOOD AND PLASTER, AND IS
SITUATED IN THE CENTER OF THE
CITY.



This method of wind bracing is of reasonable cost, is effective, and is easily applied to any tank. It consists of stringing $\frac{3}{8}$ -inch flexible steel cables across 4 diameters of the tank, and at such distances apart that the tank area is divided into 45° segments, giving the appearance, in horizontal projection, of spokes in a gigantic wheel. Two sets of cables are generally used—one in a plane about 10 feet above the bottom of the tank, and the other 20 feet above the bottom, the "spokes" in the two planes being staggered so that the shell in a 55,000-barrel tank is wind-braced at intervals of approximately 20 feet along its periphery. Some engineers place 3 sets of cables, the topmost being attached to the top angle iron. This precaution may well be used for wooden-roof tanks with wooden roof supports, but should not be necessary when steel construction is used throughout.

Formerly old sand lines that had been discarded from drilling rigs were used—hence the name. However, for obvious reasons, the use of such lines is not good practice. Cables about a drilling rig are seldom discarded until they have become badly worn and their tensile strength consequently so much decreased that there is danger that the line will break under any heavy strain, with disastrous results.

The lines are fastened to the shell of the tank by small angle irons riveted to it, or by through-going eyebolts each of which is provided with a nut, washer, and gasket on either side of the plate. At the center of the tank the lines are attached to a heavy steel ring surrounding the center post, and each radius or "spoke" is provided with a turnbuckle, so that a practically uniform tension may be obtained on all lines, and whatever adjustment from time to time is necessary to keep this tension constant can be made. As the center ring can easily be constructed in two sections, this type of wind bracing can readily be applied to completed tanks as well as to those in process of erection. The only precaution necessary is to see that the diameters upon which the lines are strung are chosen so as to clear the roof supports.

TANK ROOFS.

The tank roof specified is composed of material of sufficient thickness to permit calking. Some companies prefer to use a lighter plate and to get the necessary tightness at the seams by using a thread "weave" immersed in red lead and placed between the laps of the sheets before they are riveted together. This method cuts down the cost of construction by decreasing the amount of metal used, but is criticized by many on the ground that the light hydrocarbon gases rising from the oil will in time "cut" the saturating material of the thread "weave" and completely destroy the tightness of the joint. A further objection put forth is that the roof of a tank is the part

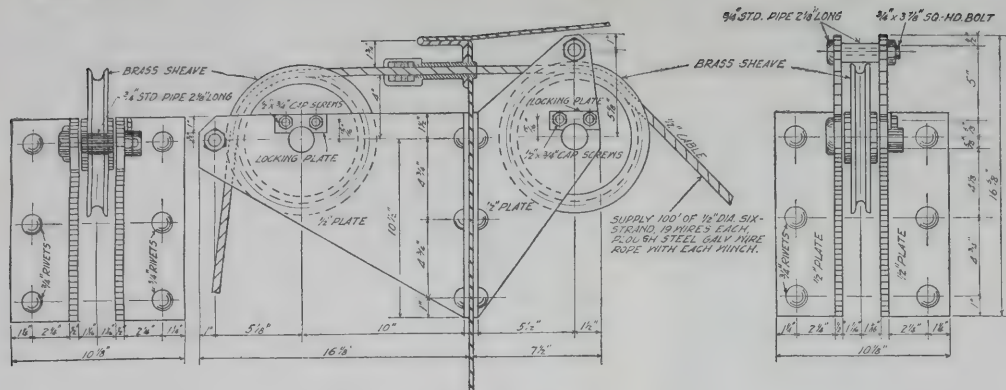
that deteriorates most rapidly owing to the action of these same hydrocarbon gases, especially if the oil contains any appreciable amount of sulphur, and a plate thinner than that which can be successfully calked (three-sixteenths of an inch) is undesirable. On the other hand, the objection can be raised to the use of the heavier material not only that it increases the cost of the tank, but that a roof is continuously subject to expansion and contraction stresses as well as to atmospheric pressures which cause it to "breathe." Thus the seams are subjected to distortion and it is questionable whether a calked joint can be kept tight.

SIZE OF PLATES.

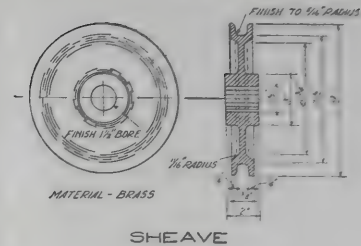
The size of plate ordinarily used for the shell of the tank is about 5 feet wide by 15 feet long (24 sheets to the ring). Six of such rings are required to obtain the necessary height of tank. Some companies, however, notably the Shell Oil Co. of California, are using sheets of sufficient width to require only 4 rings for a 30-foot tank. They are approximately 7 feet 6 inches wide and 18 feet long. By using plates of such size it is possible to eliminate two horizontal seams and four vertical seams, thus lessening the length of calked joints in the shell by more than 15 per cent. On the other hand, the amount of metal in the shell of a 4-ring tank is necessarily more than in a 6-ring tank because of the thickness of material required to satisfy proper engineering design and the impracticability of rolling a taper sheet. It is argued that if any extra thickness of metal is to be used, it should be put into the top or the bottom plates, as these are subject to the greatest deterioration by corrosive action, and not into the vertical shell. Further, the laps of sheets when properly riveted and calked seldom leak, and if leaks do occur, they can be easily repaired because of their accessibility.

SWING PIPES.

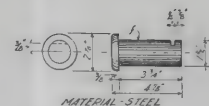
The swing pipes used by the various companies are all of the same general type, differing only as to details of construction. They range in size from 6 to 24 inches in diameter, depending upon the gravity of the oil to be handled and the size of suction line that they feed. Some operators equip their swing pipes with floats, making it possible to draw the oil from a point always at a certain definite distance below the surface by merely "slacking up" on the cable sufficiently to allow the float to carry the full weight of the pipe. There is the disadvantage, however, that should it be necessary at any time to raise the swing pipe when the tank is empty, the float makes the pipe unwieldy to handle, and if the pipe is made up of thin sheets of riveted plate, the usual practice, the resulting strain may produce leaky joints.



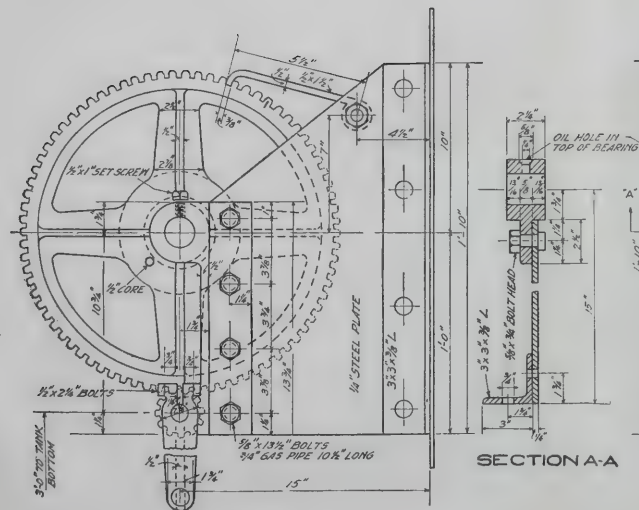
CABLE GUIDE



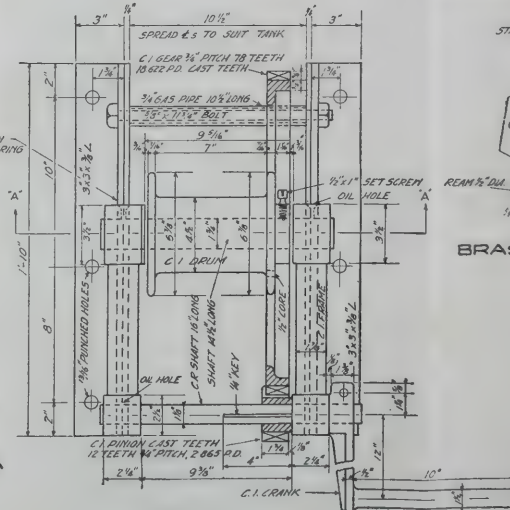
SHEAVE



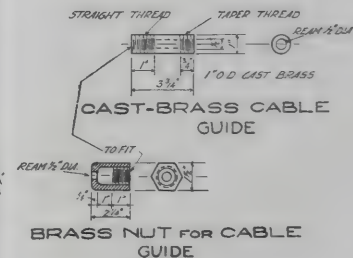
SHEAVE PIN



WINCH



WINCH



BRASS NUT FOR CABLE GUIDE

SWIVEL JOINTS FOR SWING PIPES.

Swivel joints for swing pipes are of numerous types, varying in construction from two elbows connected by a short nipple, the threads of which furnish the necessary movement for raising and lowering the end of the pipe, to somewhat cumbersome and elaborate castings employing diverse types of stuffing boxes to obtain the necessary movement required for the swing.

The swivel joint prescribed in the specifications presented appeals to the writer as one of the best of the stuffing-box type. It is composed of two cast-iron tees, one of which may be a standard stock fitting, and the other arranged with stuffing boxes upon which the swing is made. This type of fitting can be easily and effectively supported from the bottom of the tank, and as the swing pipe has a bearing on both sides of its axis, the possibility of leakage occurring in the stuffing boxes by reason of the joint opening, as may occur if the bearing is on one side of the axis only, is eliminated.

STAIRWAYS.

Stairways should be of steel throughout. A wooden structure, even though it is kept well painted, which is seldom done, soon becomes a serious fire hazard because of the seasoning and checking of the lumber. In such a condition it is also a menace to employees on account of the lumber becoming brittle. Numerous varieties of steel stairways are in use. The one shown in Plate VI is perhaps as simple as any. Some companies have the top of the stairway about $2\frac{1}{2}$ feet below the roof of the tank, the top tread being extended to form a small platform, as shown in Plate IX, A. The gage hatch is placed to the right of the center of the stairway close to the tank shell so as to be in easy reach of the gager from the platform. If the swing pipe is operated from the ground, the gager does not have to go on top of the tank, so that in obtaining his sample he is at all times protected by the hand railing on the stairway. Tank builders will usually supply without charge an iron ladder riveted to the shell. However, as this is at all times more or less coated with oil it can not be considered other than a positive danger to anyone required to use it, and especially to a man who has a case of sample bottles strapped to his back, and whose hands are necessarily smeared with oil. A tank without a stairway, preferably of steel leading from the ground to the roof is not adequately equipped.

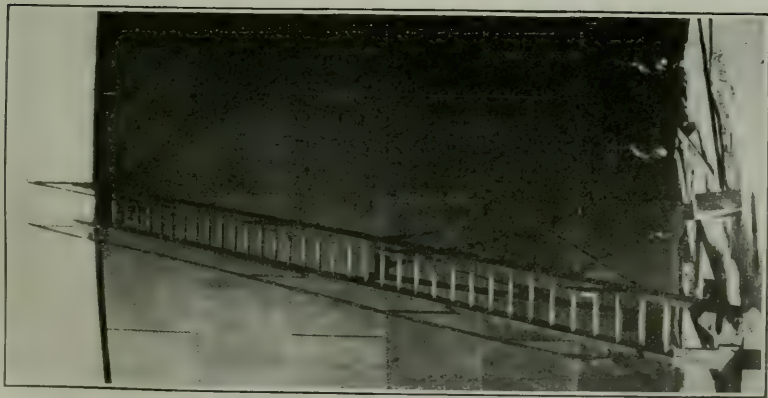
EXPLOSION DOORS.

Many companies, especially those operating in California, do not provide explosion doors for tanks other than those used for the storage of light refined products, as gasoline and kerosene. As the California

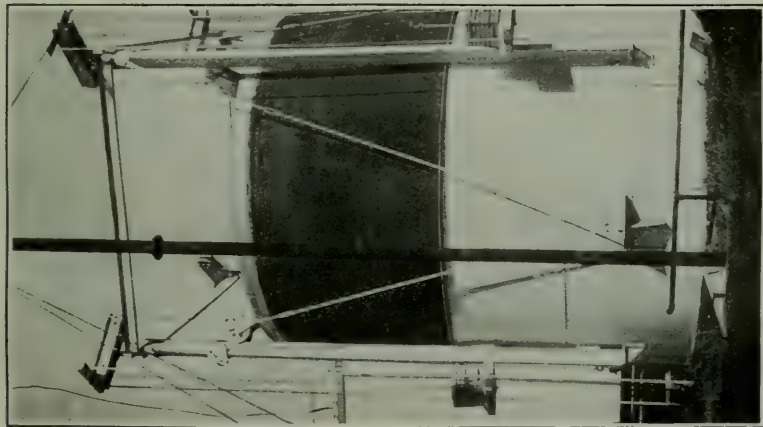
fields are seldom visited by electrical storms and the crude oils held in storage are practically all of low gravity and of asphaltum base, the dangers of fires from that source are comparatively remote, and the need of providing for such exigencies is perhaps not so urgent as in localities subject to electrical storms. However, in those sections where electrical storms are common (which seem to include all fields in the United States except those in California) it is believed that explosion doors should be provided for all storage tanks whether they contain crude oil or light refined products.

Although it is obviously impracticable to attempt to design explosion doors of sufficient area to take care of extreme conditions, as when a tank becomes almost completely filled with a mixture of hydrocarbon gases and air in the proportion best suited for rapid oxidation, it must be remembered that such conditions seldom, if ever, exist. Storage tanks when the oil is quiescent are usually kept full, and those from which oil is constantly being drawn and replaced would probably only occasionally contain the theoretical mixture conducive to explosion, there being most of the time a mixture either too rich in hydrocarbons or too rich in air. Therefore, the writer believes that where a tank is ignited, the chances are in favor of the possibility of saving at least the shell from injury, if not also the roof, by providing a reasonable number of vents through which a part of the pressure caused by an expansion of gas may be relieved. Eight explosion doors, each having an area of approximately 9 square feet, are prescribed in the specifications.

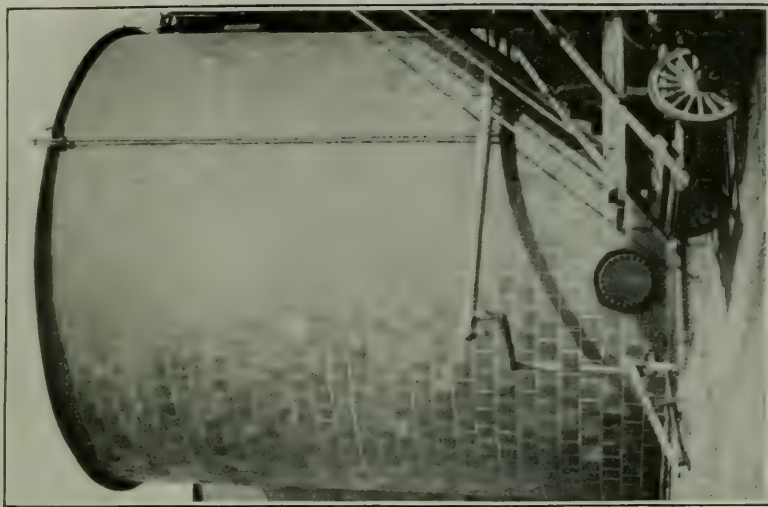
This type of door consists essentially of an aluminum plate $\frac{1}{4}$ inch thick which covers a circular hatch, and has a flange near its circumference fitting into a trough about 2 inches deep, surrounding the upper edge of the hatch. The trough is filled with a mixture of paraffin and oil, or sand and oil, to form a seal. The cover plate slides on a brass rod 2 inches in diameter, as shown on Plates VII and X, A. The upper end of the rod is supported by a plate 18 inches above the top of the hatch, which is held in place by angular supports $2\frac{1}{2}$ by $2\frac{1}{2}$ inches by $\frac{1}{4}$ inch. This rod fits in babbitt bearings at the top at the point where it passes through the aluminum plate, and in the spider beneath the plate. It is supported at the top bearing by a metal cap and hangs loose so that it is free to move on all three bearings if necessary. If an explosion occurs the pressure on the bottom of the aluminum plate is of the same intensity over its entire area. Should the bearing between the plate and the brass guide rod stick, the plate could still move upward by carrying the rod with it. When the pressure is released after the escape of the gas, the plate slides down the rod by its own weight and closes the opening.



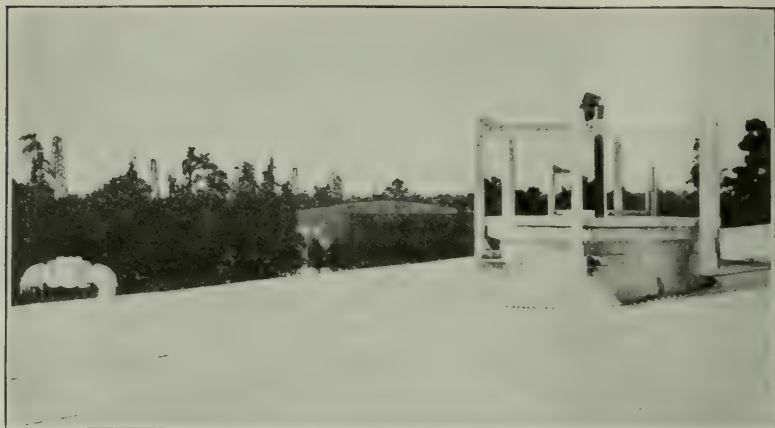
4. ALL-STEEL STAIRWAY FOR OIL TANK.



B. GASOMETER.



C. TILE-ENCASED TANK.



A. EXPLOSION DOOR AND VACUUM RELIEF VALVE.



B. "SHEEP'S FOOT" TYPE OF ROLLER.



C. WETTING DOWN LOOSE MATERIAL IN RESERVOIR BED.

VACUUM RELIEF VALVES.

A good type of vacuum relief valve to permit air to enter the tank when oil is being withdrawn is shown in Plate X, A. This consists of an ordinary stock swing-check so mounted that the check will operate to relieve a pressure from without. The lower face of the outside elbow is usually fitted with a flange and a fine-meshed wire gauze.

TANKS WITH WOODEN ROOFS.

Many companies, especially those handling heavy oils, are still constructing tanks with wooden roofs. The roofs are composed of sheathing 1 by 6 inches or 1 by 12 inches, generally sized, but sometimes laid on rough, on rafters 2 by 8 inches, supported by girders 5 by 12 inches or 6 by 12 inches, resting on posts 6 by 6 inches. Footing blocks 2 by 8 inches and about 3 feet long are usually provided for the posts. The tops of the posts where girders join are also provided with corbels of the same size and material as the footing blocks. The posts are tied together in each successive ring by sway braces of material 1 by 6 inches, placed diagonally. Some builders also tie the rings of posts together at various points. This practice, however, is not general and is of questionable benefit as regards strengthening the structure.

The sheathing boards are usually covered with a good grade of roofing paper which is essentially a deadening felt rendered waterproof by having been immersed in a hot solution of asphaltic material, and then rolled under heat and pressure. Roof coverings are also built up with layers of building paper or burlap coated and stuck together with asphaltum, and having a pebble finish on top. Such coverings should not be applied to a newly constructed roof before it has had time to season thoroughly, as the lumber in seasoning will almost surely tear the covering apart in some places and badly pucker it in others.

Sheet iron is also used for a covering for wooden roofs. The writer has seen some such roofs so well constructed that to all appearances they do not leak water and are reasonably tight even to the passage of gases. This construction has the disadvantage that the nails used for fastening on the iron will soon become loose in the sheathing on account of the wood having shrunk or become brash. There is the danger therefore that during a storm the wind may get a foothold under a sheet so loosened and tear a considerable part of the iron from the sheathing. This same objection holds true with the paper-covered roof. Once the covering of a wooden roof is gone, the wind will often wreck the sheathing and rafters as well.

Wooden roofs and wooden roof supports are objectionable also as regards fire hazard. Although it may be possible to extinguish burning oil in a tank by steam or a blanket of foam, neither of these

methods is necessarily effective in putting out a fire on the roof, so that smoldering embers may be continually dropping back into the tank only to reignite the whole mass, no matter how often the blaze along the surface of the oil may have been quenched.

COST OF TANKS.

On account of the uncertainty of the market price of manufactured products generally, owing to the present European war, it is hardly feasible to estimate the cost of steel tankage based on present figures as six months or a year hence the estimate may be abnormally high or abnormally low. At the time of the outbreak of the war, August, 1914, a tank, such as the one described with steel roof, could have been built at a cost of 30 to 32 cents a barrel, depending on the location. At present the cost would be 42 to 45 cents a barrel, whereas wooden-roofed tanks, which a little over three years ago were being erected for 25 to 27 cents a barrel, are now worth 37 to 40 cents a barrel. These figures are for completed tanks equipped with necessary swing pipe and fittings, and closed ready for the receipt of the oil, but do not include the grades for the tanks, nor pipe lines between tanks.

CONCRETE RESERVOIRS.

As stated at the outset, only concrete-lined reservoirs are here described in detail. Although a few companies at present store oil in earthen reservoirs without concrete linings, the writer has been impressed with the fact that even the officials of these companies do not in any way recommend this type of storage, but state that they are using it only as an emergency measure, or for heavy asphaltic base oils, which, owing to an overproduction, had first been stored for so long a time in tanks that practically all the lighter more volatile products had disappeared before they were put into the earthen reservoirs. The majority of such containers have been lined with several feet of clay, or some other close-grained impervious earth.

Most of the concrete-lined reservoirs in use in the United States are to be found in California. In that State there are an aggregate of 29 such reservoirs, having a total capacity of nearly 19,000,000 barrels. They are situated either in the oil fields themselves or at various points along the coast, and are used exclusively for fuel oils varying in gravity from 14° to 18° B. The lighter refining crudes are without exception stored in steel tanks.

SPECIFICATIONS FOR CONCRETE RESERVOIRS.

Typical specifications for this class of containers are presented below. The particular container described has an extreme outside

diameter of 488 feet, a total depth of about 25 feet, and a slope on the sides of 1 to 1. The roof is constructed of wood covered with roofing paper. The specifications follow.

**SPECIFICATIONS FOR CONSTRUCTION OF CONCRETE-LINED OIL-STORAGE
RESERVOIR.**

SECTION I.—GENERAL REQUIREMENTS.

(1) DEFINITION.

The ——— Company in itself, or by its duly authorized representative, shall be referred to in these specifications as the "Company."

The firm undertaking to furnish the material and erect the reservoir as herein specified, in itself, or by its duly authorized representative, shall be referred to in these specifications as the "Contractor."

At all times during the progress of the work the Contractor shall designate some person as his representative to whom instructions may be given by duly authorized representatives of the Company.

(2) LOCATION.

The reservoir shall be located on the land of the Company in sec. —, T. —, R. —.

(3) DRAWINGS.

The drawings listed below, showing the details of the construction of the reservoir, are hereby made a part of these specifications: Plates XI, XII, XIII, XIV, and XV.

The drawings and specifications are intended to supplement each other, so that the work described in the drawings and not mentioned in the specifications, or vice versa, is to be executed by the Contractor as if it were both mentioned in the specifications and shown on the drawings.

(4) SHAPE AND PLAN OF CONSTRUCTION.

The reservoir shall be circular in plan, as shown on Plate XI, and shall be constructed by making an excavation and constructing around the excavation, with the excavated material, an earthen embankment. The area within the inner crest of the embankment shall then be covered with a wooden roof, after which the bottom and the sides of the place inclosed shall be lined with concrete.

(5) DIMENSIONS, SLOPES, AREAS, AND CAPACITY OF EMBANKMENTS.

The dimensions of the reservoir are as follows:

Inside diameter at top, 488 feet.

Inside diameter at bottom, 437 feet 6 inches.

Maximum depth, approximately 25 feet 11 inches.

The slopes of the embankment shall be as follows:

Slope of embankment inside reservoir, 1 horizontal to 1 vertical.

Slope of embankment outside reservoir, 2 horizontal to 1 vertical.

Slope of embankment top of reservoir, 24 horizontal to 1 vertical.

The width of the embankment on top shall be 15 feet. The area of the bottom will be approximately 150,330 square feet. The area of the sides will be 53,200 square feet; total area, 203,530 square feet; capacity, in barrels of 42 gallons each, approximately 750,000.

(6) WORKMANSHIP.

All work in connection with the construction of the reservoir must be done in a neat workmanlike manner, and to the entire satisfaction of the Company, or its duly authorized representative.

(7) INSPECTION OF MATERIAL.

All material furnished by the Contractor as herein specified shall be of the best of its respective kind, and shall at all times be subject to inspection by the Company or its duly authorized representative, and any material that shall be found defective

and be condemned by the Company must be removed immediately by the Contractor and replaced by acceptable material.

(8) DAMAGES.

The Contractor shall at all times be responsible for damages to material that is stored in the vicinity of the reservoir site during the process of its construction, and the Contractor shall make good such damaged material by supplying new material from time to time at his own cost and expense as directed by the Company. The Contractor shall also be responsible for any damages done to the reservoir, or to any part of it, or to any property of the Company upon which the reservoir is situated, caused by the carelessness or negligence of any of his employees. The Contractor shall also be liable for all damages to tools, implements, and equipment furnished by him during the progress of the work.

(9) CARE OF MEN.

The Contractor shall have complete responsibility for the care of the men in his employ, and shall be liable for all damages by accident to such employees. He shall furnish the necessary commissary for feeding his men, and shall provide necessary tents, temporary houses, and equipment for sleeping quarters.

(10) INCOMPETENT EMPLOYEES.

The Contractor shall furnish only such men for the prosecution of the work as are competent in their particular line of employment. If any employee is judged incompetent by the Company or its duly authorized representative then the Contractor shall immediately remove such employee and shall not again employ him upon the work.

SECTION II.—EARTHWORK.

(1) NATURE OF THE WORK.

The work to be done under this section consists of excavating the necessary earth from the interior of the reservoir and depositing such excavated material in the embankments surrounding the reservoir, in accordance with plans hereto attached.

(2) EQUIPMENT.

The Contractor shall supply all the necessary labor, tools, and equipment, including picks, shovels, drills, "fresno" scrapers, wheel scrapers, road machines, tampers, and teams, and whatever equipment is necessary for properly carrying on the work.

(3) GRADE STAKES.

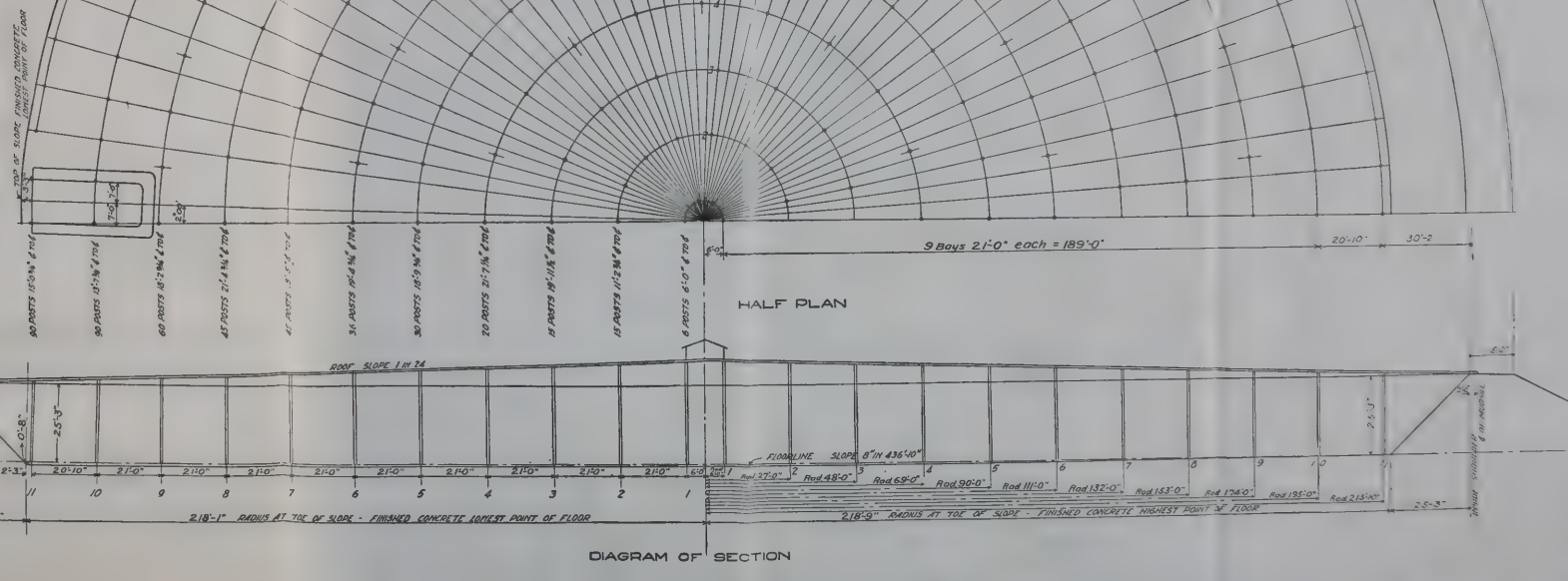
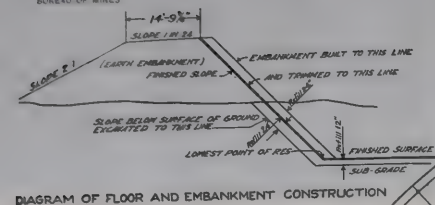
The Company shall place grade stakes wherever required about the reservoir, and the completed excavations and fills shall conform truly to the slope and outline as determined by such grade stakes, and the Company shall not be responsible for nor shall it pay for any work that does not conform to such grade stakes. The Contractor and his employees shall at all times exercise due caution in caring for grade stakes as set by the Company, and any employee willfully destroying such stakes shall be immediately discharged by the Contractor.

(4) EXCAVATION.

The exact amount of excavation shall be governed by the material that must be excavated, and shall be determined by the Company from time to time during the progress of the work. Should it be necessary in the opinion of the Company at any time to excavate more material from within the reservoir than originally intended, or to excavate material from borrow pits, the exact amount of such excavation shall be carefully determined by the Company by cross section, and the additional yardage shall be paid for at the same rate as the yardage from the original excavation.

(5) STRIPPING THE SURFACE SOIL.

The Contractor shall first strip the entire site of the reservoir, both that portion in cut and that portion to be covered by embankment, of all vegetable matter and top soil. This stripping shall extend to a depth of at least 8 inches below the surface and to whatever greater depth may in the judgment of the Company be required. The





material so stripped shall be removed from the area and placed in fire levees surrounding the reservoir site, or at other points in the vicinity of the reservoir, as directed by the Company.

(6) OIL AND WATER DRAINS.

Two 12-inch oil lines and one 8-inch water drain shall be placed beneath the embankment, as shown on Plate XII, at such positions as shall be designated by the Company.

Ditches for these pipes shall be dug by the Contractor immediately after the surface soil has been stripped. Pipe shall be furnished and laid by the Company. The Contractor, however, shall do the work of backfilling the ditches, also of placing the concrete blocks, as shown on Plate XII.

(7) BUILDING UP THE EMBANKMENT.

The area beneath the embankment shall be plowed by the Contractor, thoroughly harrowed, and moistened with water to the satisfaction of the Company. The embankment shall then be built with material excavated from within the reservoir, or, if need be, from pits in the vicinity of the reservoir. The material may be excavated and placed in the embankment by wheel scrapers, "fresno" scrapers, or wagons. It shall, however, not be deposited in layers more than 3 inches thick, and where necessary road machines shall be employed to insure the proper spreading of the material in the embankment. Under no conditions shall material be dumped onto the embankment in a pile and not spread.

All material placed in the embankment shall be moistened with water before being loaded into the scrapers or wagons, and shall again be moistened after having been spread. Any excavated material from within the reservoir that, in the judgment of the Company, is not fit to be placed in the embankment shall be placed by the Contractor at a point outside the reservoir site, as designated by the Company.

When the material has been placed in thin layers in the embankment and moistened as specified, it shall then be tamped by at least two roller tampers of the sheep's foot type. Each tamper shall be drawn by a 4-horse team, and shall be driven around the top of the fill, making at least 10 complete circuits of the reservoir per hour.

Water for wetting material shall be furnished by the Company, and shall be brought by the Company in water mains surrounding the outer circumference of the reservoir and at a distance of about 20 feet from the outside toe of the embankment. The Contractor shall furnish and shall lay all necessary laterals from this water main into the reservoir site, and shall move such laterals from time to time as may be required by the progress of the work.

(8) BORROW PITS.

Where necessary, borrow pits shall be designated by the Company in the vicinity of the reservoir site. The nearest rim of such a borrow pit shall be at a distance not less than 200 feet from the outer toe of the reservoir embankment, and the farthest rim of such a borrow pit shall be at a distance not to exceed 400 feet from the toe of the embankment. If it is necessary to so locate a borrow pit that its nearest rim is a greater distance than 600 feet from the outer toe of the reservoir embankment, the Contractor shall receive extra compensation for the removal of such material as shall be determined on at the time.

(9) RUNWAYS TO EMBANKMENT.

In the construction of the embankment the Contractor shall build runways for the removal of the material from the excavation inside the reservoir to the embankment. These runways shall be located by the Company, and shall be spaced at a distance not less than 100 feet apart. The scrapers, wagons, teams, etc., in carrying the dirt from the excavation to the embankment shall be driven up one runway and shall return to the excavation along the top of the embankment and down the next adjacent runway.

(10) THE INSIDE SLOPE.

To obtain a homogenous and compact surface to the inner slope of the embankment, the inner slope shall be built and finished in the following manner. The embankment of the reservoir shall first be built up as above provided in these specifications. The excavation shall be so made that the inner slope shall be about the width of a wheel scraper beyond the line of the desired finished slope, beginning at the bottom of the reservoir which shall be excavated for a distance of about one foot below the position of the concrete lining. The inner slope shall then be built up by material excavated from within the reservoir, deposited by wheel scrapers in thin horizontal layers, and shall be moistened and thoroughly tamped by the sheep's foot tampers. This inner embankment, or earthen lining, shall be bound to the original embankment and slope by first plowing or otherwise roughening the original slope and embankment. When this lining is thus built up it shall be allowed to stand for at least 3 days before being trimmed to grade. The inner face of the embankment so built up shall then be trimmed to a true and even slope to conform with the dimensions of the reservoir as herein set forth.

(11) TOP OF THE EMBANKMENT.

The top of the embankment shall be built at least 2 inches higher than the finished top, and shall be made smooth and even and brought to proper grade.

(12) OUTSIDE SLOPE.

As herein specified, the outside slope of the embankment shall be 2 horizontal to 1 vertical. It shall be built up compactly, and neatly finished, and upon completion shall be oiled by the Contractor for a distance of 3 feet beyond the toe of the embankment. Oil shall be furnished by the Company on the ground and the Contractor shall provide the necessary equipment for sprinkling the oil upon the embankment.

(13) BOTTOM OF RESERVOIR.

The bottom of the reservoir shall be excavated to a subgrade 1 foot below the finished grade. It shall then be thoroughly plowed, harrowed, moistened, and compacted. Suitable refilling material shall then be spread over it to bring it up to the finished grade. The refilling material shall be spread on in thin layers as specified for the embankment, and shall be thoroughly moistened and rolled. The roller used on this work shall have a smooth surface, and shall weigh no less than 5 tons.

(14) EXCAVATION FOR POST FOOTINGS AND SWING-PIPE PIT.

When the bottom of the reservoir has been brought to the proper grade, the Contractor shall make excavations for the concrete footings for the posts, for the swing-pipe pit, and for the joint between the floor and the side slabs as designated by the Company. The Contractor shall remove from the inside of the reservoir all such material excavated, and shall place it at positions designated by the Company or its duly authorized representative.

(15) EXTRA WORK.

Extra work unless otherwise stated shall be done by force account, but under no conditions shall extra work be performed by the Contractor, or paid for by the Company, without written authority from the Company.

SECTION III.—ROOF.**(1) NATURE OF THE WORK.**

The work to be done, under this section, consists in the erection of a wooden roof over the reservoir as herein specified, and in accordance with drawings hereto attached.

(2) MATERIAL AND EQUIPMENT.

The Contractor shall supply all the necessary material, equipment, and labor for the construction of the roof. All such material shall be the best of its respective kind, and shall be subject at all times to the inspection of the Company or its duly authorized representative. It shall conform to the sizes as designated on the drawings.



DETAILS OF SUMP AND SWING PIPE FOR 750,000-BARREL CONCRETE-LINED RESERVOIR.



(3) ROOF SUPPORTS AND PIERS.

Roof supports shall be wooden posts 8 by 8 inches, as designated on Plates XIII and XIV. The posts shall rest on concrete piers, as shown on the drawings, and shall be centered by one dowel pin, $\frac{5}{8}$ inch by 6 inches, in each pier. For the convenience of the Contractor piers may be poured in two sections, one pouring bringing the pier flush with the surface of the ground, after which the reinforcement fabric for the bottom may be placed in position, and the second pouring may be made, bringing the top of the pier to the desired grade and having the floor fabric embedded in it at the proper point so that fabric may form a continuous reinforcement for the floor slabs (see paragraph 5, section IV). The tops of the piers on the bottom of the reservoir shall be in the same plane, and the piers shall be kept damp for at least six days after having been poured before posts may be erected on them.

(4) ROOF GIRDERS.

The girders shall be of 4-inch by 14-inch material, and of lengths as shown on Plates XIII and XIV. They shall be fastened to the posts with $\frac{5}{8}$ -inch by 18-inch drift pins. Girders and posts shall be fastened together by knee braces, as shown on the drawings, of 2-inch by 6-inch material. Knee braces shall be bolted to posts and girders by at least two $\frac{3}{4}$ -inch carriage bolts. Corbels, as shown on Plate XIV, shall be placed on tops of posts in rows 2, 3, 4, and 5, and shall be drifted through with $\frac{5}{8}$ -inch by 24-inch drift pins, as shown.

(5) RAFTERS AND MUD SILLS.

All rafters shall be of 2-inch by 8-inch material, and of lengths as shown on drawings. The outer row of the rafters shall rest on a 2-inch by 12-inch redwood mud sill, as shown on Plate XIII, and shall be notched so as to bear on the full width of the mud sill. A line of 2-inch by 3-inch double bridging shall be placed between the rafters in the middle of each bay, with the exception of the bays of the outer row. In the outer row of bays three lines of such bridging shall be placed as directed by the Company. Bridging shall be nailed in position before sheathing is put on, and two 10d nails shall be used in the end of each bridging. The rafters shall be toe-nailed to the girders with 10d nails, using at least 3 at each rafter. Rafters that lap shall be thoroughly spiked together with 20d spikes, and where joints abut shall be spliced with 2-inch by 8-inch material and thoroughly spiked. The space between rafters at the embankments shall be completely closed by 2-inch by 8-inch material.

(6) SHEATHING.

The roof shall be sheathed with 1-inch by 8-inch sheathing surfaced on one side, furnished in assorted lengths from 8 feet to 16 feet. Sheathing to be No. 1 material, free from knots, pitch pockets or shakes. The roof shall be laid, as shown on Plate XIV, to break joints with roof paper.

Before the sheathing is laid the top of rafters shall be trimmed off with adzes where necessary to insure that sheathing will rest securely on each rafter and will lie smooth and flat. A space of approximately $\frac{3}{8}$ inch shall be left between each board to allow for swelling and shrinkage. Each board shall be nailed with at least three 8d nails on each rafter. All the roof supports and the sheathing, with the exception of a ring approximately 10 feet in width around the circumference of reservoir, necessary for handling the concrete materials, shall all be placed in position before any of the concrete material other than the post footings shall be poured.

(7) VENTILATOR, LADDERS, WALK, HATCH, ETC.

One ventilator, as shown on Plate XIV, shall be constructed on the roof at the center of the reservoir. Contractor shall also place a stairway from the bottom of the reservoir to the top on the inside as designated on Plate XII, and one stairway from the outside toe of the slope to the top of the embankment, to be located in the field by the Company. A wooden walk way shall be constructed by the Contractor from the edge of the roof to the center, having branches to the winch boxes. This wooden walk way shall be composed of 2-inch by 4-inch stringers, and 2-inch by 8-inch planks 2 feet wide, laid with intervening spaces of about $\frac{1}{2}$ inch. The roof of the tank is also

to be equipped with a properly constructed hatch placed at the head of the stairway as shown on Plate XII.

(8) NAILS.

The contractor shall furnish all nails required in the work, to be of sizes as designated in the specifications and drawings.

(9) ROOFING PAPER.

When the woodwork of the roof has been completed, before any roofing paper shall be placed in position, the sheathing shall be thoroughly swept and cleaned of all sawdust, dirt, gravel, chips, shavings, or other material, particular care being taken that no nails are left lying on, or partly imbedded in, the roof. All loose or projecting knots shall be removed, and knot holes exceeding 1 inch in diameter shall be covered with tin plates securely nailed on. The sheathing shall then be covered and made water-tight by placing one layer of 3-ply roofing paper of a quality to be approved by the Company or its duly authorized representative. This paper shall be laid in accordance with Plate XIV. Laps of paper shall be thoroughly cemented together and then nailed with No. 12 roofing nails, the maximum spacing between nails to be $1\frac{1}{2}$ inches.

After the roofing paper has been laid in place, no unnecessary material of any sort shall be wheeled or carried over it, or stored upon it, and as little walking as possible shall be done upon it.

(10) ASPHALT AND GRAVEL COATING.

When the roofing paper has been placed in position as above specified, a heavy coating of hot asphalt, at least $3\frac{1}{2}$ pounds per square yard, shall be applied, and a coating of hot gravel shall immediately be applied to the asphalt. As much gravel shall be used as is held by the asphalt. After cooling, the excess loose gravel shall be removed. Particular care must be taken that hot gravel is applied to hot asphaltum, and that a thorough bond is made between the gravel and the asphalt. If such a bond is not made in any part of the covering, the Contractor shall remove that part, including the roof paper, and shall replace it to the satisfaction of the Company.

(11) ROOFING GRAVEL.

The roofing gravel shall be furnished by the Contractor. It shall be composed of pebbles rejected by a screen having $\frac{3}{8}$ -inch openings and passing through a screen having $\frac{5}{16}$ -inch openings. Gravel shall at all times be subject to inspection by the Company or its duly authorized representative.

(12) WINCH BOX.

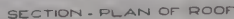
The Contractor shall install on the roof of the completed tank, as directed by the Engineer, two (2) standard iron winch boxes which will be furnished on the ground by the Company.

(13) DRAINS AND GUTTERS.

Gutters shall be constructed entirely around the outer edge of the roof, as shown on Plate XIV. The drains from these gutters and downspouts leading from the outer slope of the embankment shall be constructed as shown on Plates XIII and XIV. The galvanized-iron drains shall be furnished by the Contractor and shall be of No. 24 gage iron. The openings leading from the gutters to the downspouts shall be thoroughly and carefully flashed with roofing paper, and all joints shall be covered with hot asphaltic cement so as to make a water-tight job. All drains leading down the slope of the embankment shall be constructed of wood, as per detail drawing, and shall extend at least 10 feet beyond the toe of the slope.

(14) CLEANING UP.

Upon completion of the roof, the bottom of the tank and the inside slopes shall be thoroughly cleaned of all small pieces of wood, roofing paper, nails, refuse, etc., which shall be disposed of by the Contractor as directed by the Company.



DETAILS OF ROOF FRAMING AND CONCRETE LINING OF 750,000-BARREL RESERVOIR

SECTION IV.—CONCRETE.

(1) NATURE OF THE WORK.

The work to be done by the Contractor under this section consists of constructing upon the sides and bottom of the reservoir, in a thoroughly workmanlike manner, a lining of concrete 3 inches in thickness, reinforced with metallic fabric as herein-after specified, and so carefully poured and compacted as to be as nearly as possible water-tight. Under no condition shall any of the concrete for the sides or floor be poured until the framework and sheathing of the roof, with the exception of the 10-foot strip around the circumference of the reservoir as hereinabove specified, shall have been erected. The piers for roof supports must, of course, be constructed before the erection of the roof, as provided in paragraph 3 of section III.

(2) MATERIALS, LABOR, TOOLS, ETC.

The Contractor shall furnish all materials, labor, tools, mixers, barrows, carts, cars, skips, engines, teams, wagons, etc., and any and all other tools and equipment necessary to perform the work as herein described.

(a) CEMENT.

A good grade of Portland cement satisfactory to the Company or its duly authorized representative shall be furnished by the Contractor. Cement may be supplied either in barrels or in sacks, at the option of the Contractor. It shall, however, at all times be subject to the inspection of the Company, the Company reserving the right to reject any and all cement that test shows to be not up to requirements.

(b) SAND.

The Contractor shall furnish the necessary sand for the contract. The sand must be clean and sharp and free from earth, clay, shell, gypsum, mica, or other injurious material.

(c) ROCK.

Crushed rock shall be furnished by the Contractor in sizes as follows:

One-half-inch rock, which shall be retained on a $\frac{1}{4}$ -inch mesh screen, and shall pass through a $\frac{1}{2}$ -inch mesh screen.

One-inch rock, which shall be retained on a $\frac{1}{2}$ -inch mesh screen, and shall pass through a 1-inch mesh screen.

It shall be of a quality approved by the Company, and shall contain no clay or earthy substances or volcanic ash.

(d) REINFORCING MATERIAL.

The reinforcing material used in the bottom and on the sides of the tank shall be welded metal fabric, having a 4-inch-by-4-inch mesh, and composed of No. 6 gage wires both ways. This fabric shall be furnished in rolls 86 inches in width and approximately 240 feet long. The Contractor shall supply, cut, and shape the reinforcing fabric as shown on Plate XV.

(3) WATER FOR CONCRETE.

The water for concrete shall be furnished by the Company and shall be supplied through the water mains surrounding the outer circumference of the reservoir, as provided for in paragraph 7, section II. The Contractor shall furnish and lay all necessary laterals from these water mains to the various positions along the edge of the reservoir where he may have his concrete mixers in operation.

(4) PREPARATION OF THE RESERVOIR FOR CONCRETE.

The final preparation for the pouring of the concrete shall be made by carefully bringing all parts of the bottom and inside of the reservoir to the finished grade. The Contractor shall also at this time excavate for the joint at the toe of the slope and shall remove all material so excavated, together with all material taken off in finishing to exact grades from the inside of the reservoir.

(5) PLACING REINFORCEMENT.

All reinforcement fabric for the bottom of the reservoir shall be laid before the roof is put in place, as specified in section III, paragraph 3, and must extend continuously along the bottom and sides of the reservoir through the foundation piers for the posts. Longitudinal splices shall be lapped at least one mesh and shall be wired together with No. 16 gage annealed iron wire to be furnished by the Contractor. All reinforcement must be properly stretched and made to lie flat. Transverse splices in reinforcement shall lap 24 inches. When the reinforcement is in place, and before pouring is begun, care must be taken that all stakes, pins, bolts, etc., used in laying and stretching the fabric are removed. The fabric must be so placed over the entire area that it can readily be pulled into position in the center of the concrete slab as the pouring progresses. Arrangement of reinforcing material is shown on Plate XV.

(6) JOINT AT TOE OF SLOPE.

A wooden joint of 1-by-6-inch material shall be placed in the concrete at the toe of the slope inside the reservoir, as shown in detail on Plate XVI. The metal fabric laid upon the slopes and the bottom of the reservoir shall pass through the wooden frame in the joint, as shown on the drawing, and shall be so laid as to form a continuous reinforcement, tying sides and bottom together.

(7) PROPORTIONING CONCRETE MATERIAL.

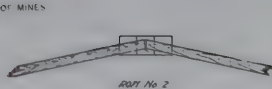
The concrete for the bottom of the reservoir and for the piers supporting the roof shall be composed of one part of Portland cement, two and one-half parts of sand, two parts of $\frac{1}{2}$ -inch crushed rock, and two and one-half parts of 1-inch crushed rock. The concrete for the sides of the reservoir shall be composed of one part of Portland cement, two and one-half parts of sand, and two parts of $\frac{1}{2}$ -inch crushed rock. The proportions of the various materials shall be very carefully measured at all times by the Contractor. The Company, however, reserves the right to change from this proportion as it sees fit, and no such changes shall in any way be construed to affect the contract price.

(8) MIXING AND POURING CONCRETE.

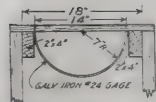
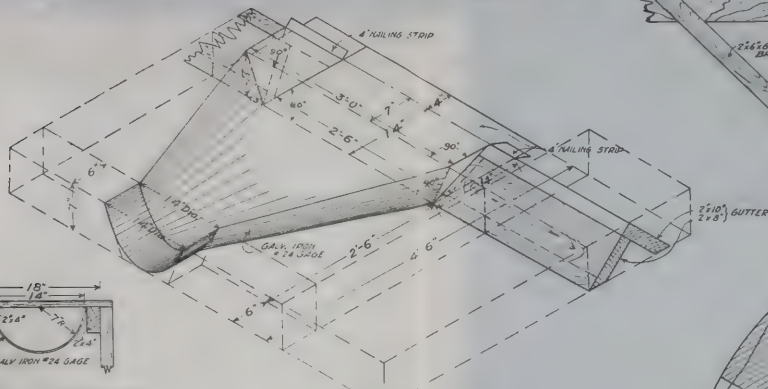
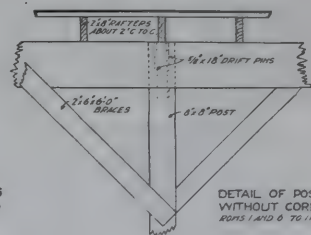
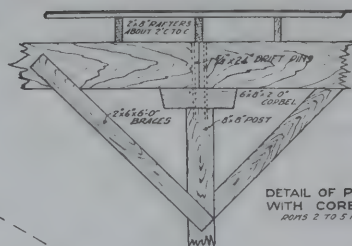
The bottom of the reservoir and the side slopes shall be thoroughly wetted before any concrete material is poured on them. In sprinkling, however, the Contractor shall see that no reinforcing fabric becomes dirty or muddy; and if any dirt does adhere to the fabric it shall be thoroughly removed before any concrete material is poured on it. The mixing shall be done in batch mixers of a form and type approved by the Company. No more water shall be added to the material than is absolutely necessary to cause the concrete to spread properly over the area to be covered. On both the floor and the side slopes a layer of concrete approximately $1\frac{1}{2}$ inches thick shall first be poured. The reinforcing fabric shall then be drawn up through the concrete and allowed to rest on top of it. As soon as the fabric has been drawn up, and before the first layer of concrete shall have obtained its initial set, a second layer shall be immediately poured, bringing the slab up to the required thickness. When the pouring has been completed, the surface of the concrete must be immediately tamped with wooden tampers and then finished smooth and close-grained by troweling. The Contractor must at all times exercise especial care that the position of the wire fabric is as nearly as possible in the center of the slab. He must also furnish men experienced in troweling and floating the surface of the concrete, in order that it may be made as nearly waterproof as possible.

(9) JOINTS IN CONCRETE.

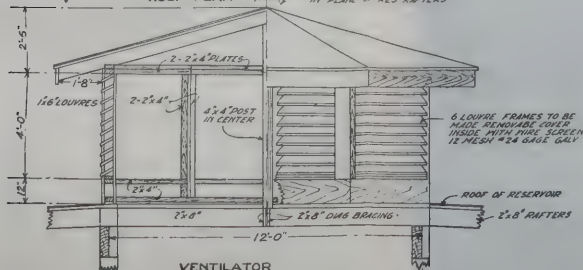
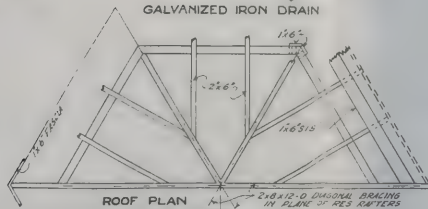
Upon the completion of a day's pouring the edges of concrete slabs shall be roughly beveled off. When work is resumed, this beveled edge shall be thoroughly cleaned, dampened, and well brushed with neat-cement grout before the next section of concrete is poured.



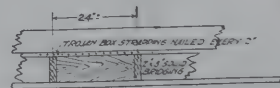
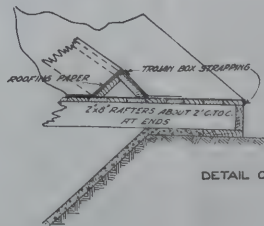
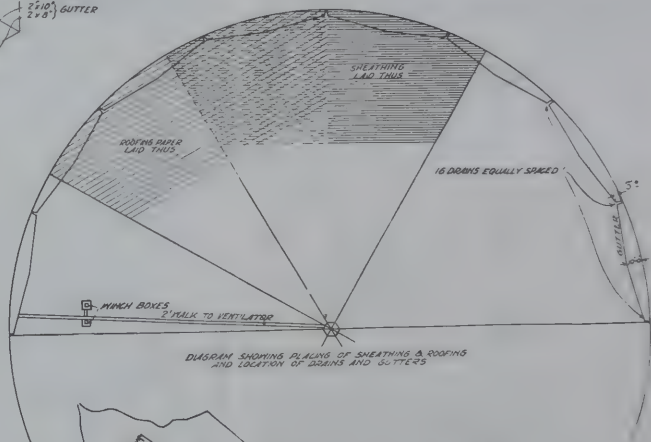
DIAGRAMS OF GIRDER JOINTS
ROOFS 1 TO 4 INCL.



GALVANIZED IRON DRAIN



VENTILATOR



DETAILS OF ROOFING FOR 750,000-BARREL CONCRETE-LINED RESERVOIR.

(5) PLAC

All re
roof is p
tinuous
for the
wired to
All rei
splices
and be
used in
over th
concre
shown

(6) Jo

A w
of the
laid u
frame
tinuo

(7) P

Th
shall
two j
The
ceme
prop
by t
prop
the

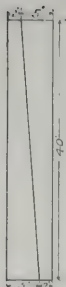
(8)

T
con
tha
the
on
the
ne
bo
sh
co
an
sh
th
ta
el
of
fr
o
(

h

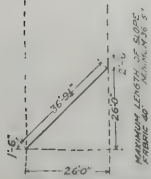
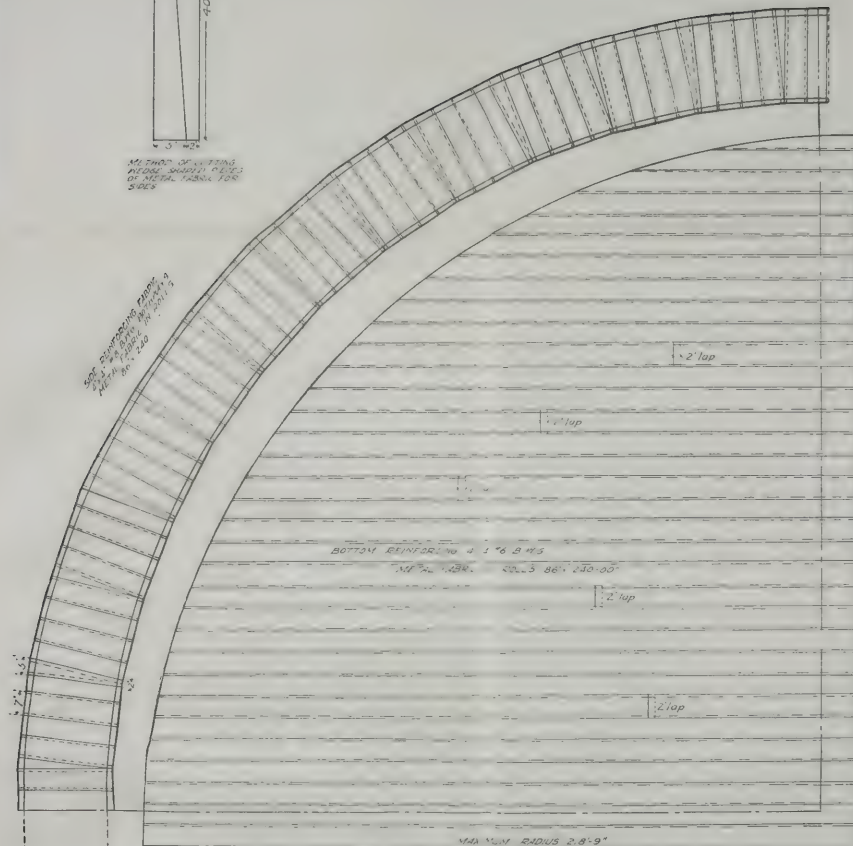
c

FRIEDL 1911



METHOD OF LAPPING
ALONG INSIDE EDGES
OF METAL TANK FOR
SIDES

SEE DRAWING PLATE 27
FOR DETAILS OF
LAPPING OF
METAL TANK FOR
SIDES



REINFORCING FABRIC					
POSITION	MESH	NO. OF BARS	NO. OF PIECES	NO. OF PIECES	TOTAL SQ. FT.
BOTTOM	4'-0" x 8'-0"	80	240	97	166,560
SIDES	4'-0" x 8'-0"	80	240	39	67,080

ARRANGEMENT OF REINFORCING MATERIAL FOR CONCRETE-LINED RESERVOIR, CAPACITY 750,000 BARRELS.

(E
ro
ti
fr
w
d
s
a
t
c
c
e
(



(10) SPRINKLING FINISHED WORK.

The Contractor shall keep all of the finished concrete moistened as directed by the Company until the final completion and acceptance of the reservoir by the Company.

(11) GROUTING:

Should small shrinkage cracks appear in any part of the floors or slopes at any time during the concreting, they shall be filled with a cement grout as directed by the Company. After the concrete has been allowed to stand for a period of 20 days, both the floor and the slopes shall be grouted with cement wash of a proportion to be determined by the Company or its duly authorized representative.

GENERAL DETAILS REGARDING RESERVOIR CONSTRUCTION.**CHOICE OF SITE FOR RESERVOIR.**

One of the most important factors upon which the success of a reservoir depends is the judicious choice of the site. The soil should be of homogeneous texture, preferably a sandy clay in which clay predominates. The site should be well drained in order that any surface waters that may percolate through the embankment and get behind the concrete lining may be carried away and not allowed to stand, thereby placing on the sides and bottom a hydrostatic pressure from without that may cause the concrete to crack when the reservoir is empty. It has been suggested that in large reservoirs drain tiles insuring the prompt removal of surface water might well be placed beneath the excavation. No site should be chosen such that the level of adjacent standing water, such as back-water from the arm of a river or bay, will at any time be above the level of the bottom of the completed reservoir. When strata or pockets of sand or other loose material extending into the subgrade are encountered they should invariably be removed for a distance of 3 feet or more below the finished excavation and then refilled to grade with selected earth, put on in thin layers and carefully tamped.

BUILDING EMBANKMENT.

In building up the embankment the "sheep's foot" type of roller tamper (Pl. X, B) has proved most effective. A "road machine" or road grader has been successfully used by some contractors for spreading the material, and a heavy harrow or a drag scraper has been used for breaking clods.

Wetting down the loose material is effective in enabling the tampers to build a compact embankment, in making the earth ride satisfactorily in the scrapers, and in keeping down the dust. The usual method of sprinkling is shown in Plate X, C.

On completion of the main embankment and the refill on the inner slope it is necessary to trim from the inner slope a foot or more of material to bring it to the true grade and to prepare it for the concrete lining. Grade stakes are set on radial lines at the top and at the inner toe of the slope at distances of approximately 10

feet apart around the circumference of the reservoir. Narrow trenches about 6 inches wide are then dug to grade by the use of mattocks and slope-level boards and 2-inch by 4-inch strips 38 feet long placed flat against the finished surface. The trimming between these slope strips is then done by hand or by especially devised scrapers ^a (Pl. XVI, A and B).

OUTSIDE SLOPE.

The outside slope of the embankment, shown in Plate XVII, A, when finished should be thoroughly sprinkled with oil, which not only prevents the washing of the earth by heavy rains but retards the growth of grass and weeds which when dry become a serious fire menace. It is good practice when the reservoir is in use to oil the slope two or three times a year, or often enough to keep it free from vegetation. A rapid and successful means of oiling is shown in Plate XVII, A. An ordinary 500-gallon tank wagon arranged with a sprinkler spout having an extended arm on one side so that the outer perforations will deliver the oil well toward the toe of the embankment is used. The lower part of the slope is reached from the ground surface.

ROOF.

As previously stated, the roofs of all the large reservoirs so far constructed have been of wood covered with roofing paper. In the opinion of the writer this type of construction is unsatisfactory, as it not only permits the sun's rays to heat the upper surface of the oil but it offers no resistance to the passage of the light hydrocarbon compounds that rise from the body of the oil by reason of such heating.

A reinforced-concrete roof would certainly be a much more permanent type of construction, and a concrete roof made sufficiently strong to uphold a foot or more of earth and tight enough to shed seepage water would be an ideal construction. By this means a low and practically constant temperature could be maintained within the reservoir at all times, and injuries to the concrete lining through expansion and contraction and losses by evaporation would be reduced to a minimum.

Various stages of the roof construction are shown in Plates XVII, B, XVIII, A, and XVIII, B.

CONCRETE LINING.

Too great stress can not be placed on the necessity of thoroughly mixing and tamping the concrete lining, as imperviousness of the lining is quite as important as a proper backing for it. It is abso-

^a Cole, E. D., Concrete-lined oil-storage reservoirs in California; construction method and cost data: Proc. Am. Soc. Civ. Eng., vol. 41, August, 1915, pp. 1327-1350.



A. TRIMMING SLOPE BY HAND.



B. TRIMMING SLOPE WITH SPECIAL SCRAPER.



A. OILING THE COMPLETED EMBANKMENT.



B. INCOMPLETED TANK, ROOF CONSTRUCTION BEGUN AND REINFORCING MATERIAL IN PLACE.



C. EXCAVATING FOR JOINT BETWEEN FLOOR AND SIDE OF CONCRETE LINING.

lutely essential that the finished concrete be dense and have a dense close-grained glazed surface. To obtain this result a mechanical analysis of the aggregates to ascertain their proper proportions in the mix should be taken repeatedly during the progress of the work. The method for determining the proper proportions, described by Fuller and Thompson,^a has been successfully used.

EXPANSION JOINTS.

It will be noticed that the foregoing specifications make no provision for expansion joints in the concrete other than the joint between the floor and the side slopes formed by the small wooden form of L cross section. This is not strictly an expansion joint, as the reinforcement is carried through it from the sides to the bottom. It forms a convenient line to which to pour, and in the more recently constructed reservoirs the form has been removed entirely before the slope concrete has been poured. Excavation for this joint is shown in Plate XVII, *C*.

In the first reservoirs constructed various types of expansion joints were used, but none has proved satisfactory. In fact, more than one company has spent a considerable sum of money in removing entirely the expansion joints from some of their reservoirs, which they found to be leaking badly.

Reed,^b in a discussion before the American Society of Civil Engineers, stated that it is his "belief that expansion joints are not necessary in work of this type, provided there is sufficient reinforcement in the slab and the concrete is carefully cured." The writer is inclined to agree with Reed, especially if the reservoir is comparatively well filled at all times, and when fresh oil is added in any appreciable amount care is taken to see that it is reasonably cold and is delivered into the reservoir well toward the center of the oil already contained and not against the concrete lining. Even when it is necessary to withdraw all the oil from the reservoir there is no reason why a sufficient volume of water can not be placed in it to keep the air at all times cool and moist.

^a Fuller, W. B., and Thompson, S. E., The laws of proportioning concrete: Trans. Am. Soc. Civ. Eng., vol. 59, December, 1907, pp. 67-143.

^b Reed, R. J., Concrete-lined oil-storage reservoirs in California; construction methods and cost of data: Proc. Am. Soc. Civ. Eng., vol. 42, February, 1916, pp. 229-232.

TEMPERATURE VARIATIONS.

Temperature variations throughout the year in a storage reservoir filled with oil are surprisingly small, as is indicated by Table 3 following:

TABLE 3.—*Temperatures without and at various points within K. T. & O. Reservoir No. 2, Bakersfield, Cal.*

[Capacity of reservoir, 500,000 barrels; depth, 21 feet; depth of oil, 19 feet 9 inches (approximately); gravity of oil, 14° B.]

Date.	Atmospheric temperature, °F.	Temperature of oil, °F.			
		2½ feet from bottom.	7½ feet from bottom.	12½ feet from bottom.	17½ feet from bottom.
1914.					
June 1	76	57	57	60	65
July 1	87	62	62	62	69
Aug. 1	86	60	60	66	73
Sept. 1	60	62	61	64	72
Oct. 1	60	62	62	67	72
Nov. 1	62	64	64	65	68
Dec. 1	48	59	59	59	59
1915.					
Jan. 1	37	56	56	56	56
Feb. 1	50	54	53	53	53
Mar. 1	48	54	54	54	54
Apr. 1	58	53	53	54	55
May 1	56	55	55	55	59
June 1	70	56	56	56	62
July 1	80	57	59	63	62

Extreme variation in atmospheric temperature, °F..... 50

Extreme variation in temperature of oil 2½ feet from bottom, °F. 9

Extreme variation in temperature of oil 7½ feet from bottom, °F. 11

Extreme variation in temperature of oil 12½ feet from bottom, °F. 14

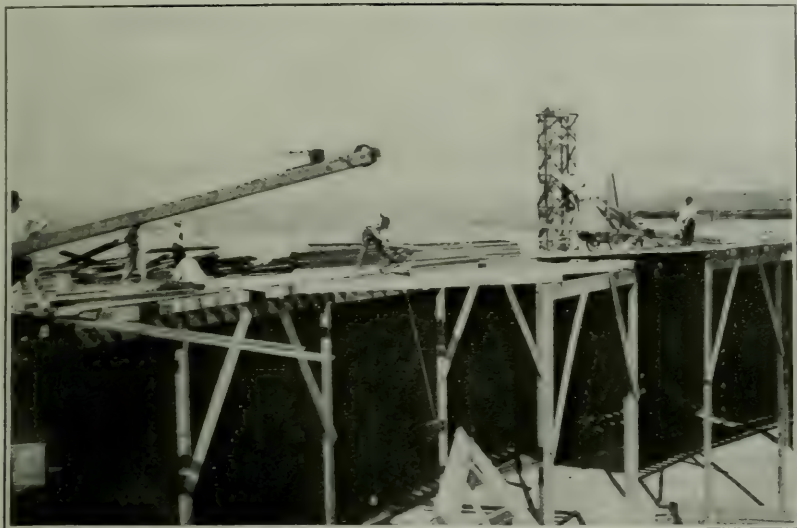
Extreme variation in temperature of oil 17½ feet from bottom, °F. 20

Temperatures taken at 7 a. m.

The atmospheric temperature was taken at 7 o'clock in the morning, so that the extreme variation in atmospheric temperature shown is not the maximum variation. The highest temperature for the period was 106° F. at 3 p. m. on August 1, 1914, and the lowest 32° F. at 4 a. m., January 1, 1915, so that the actual extreme variation in atmospheric temperature was 74°. It is safe to say, however, that the highest and lowest temperatures recorded for the oil near the bottom of the reservoir represent very nearly the actual conditions for the period.

EFFECT OF OIL ON CONCRETE.

Where proper care has been taken to make a dense compact lining in which all coarse material is well embedded below the surface there seems no doubt that an oil-tight structure can be made. The writer has repeatedly seen samples of concrete lining taken from the bottoms of reservoirs 20 feet in depth which have been in use for a period of



A. LIFTING ROOF SUPPORTS INTO POSITION.



B. SHEATHED ROOF READY FOR ROOFING PAPER.

five years. These have shown practically no penetration whatever. Mr. H. B. Truett, chief engineer of the fuel-oil department of the Southern Pacific Railroad, states that he examined a 750,000-barrel reservoir belonging to the company after it had been in continuous use for several years, and found the concrete lining in practically perfect condition. A scratch with a penknife removed the oil from the surface of the lining and showed the concrete white and unattacked in almost every place examined, and he found numerous places where the oil could be wiped from the surface of the lining, leaving it scarcely discolored and as smooth and firm as the day it was put in.

W. E. Perdew, chemist for the same company, has made a study of the action of oil on oil-proofing materials and on what was determined by mechanical analysis of the aggregates to be a desirable mix of concrete.

The following abstract of a report made by him shows the results of his experiments:

Concrete blocks 6 by 12 by 3 inches were made from the same materials mixed in the same proportions as were used in reservoirs Nos. 3 and 4, section 7, Kern River. This mix in parts by volume was as follows:

Aggregate.	Proportion.
Cement.....	1.0
Sand.....	2.5
$\frac{3}{4}$ -inch rock.....	1.5
1 $\frac{1}{2}$ -inch rock	3.0

After these bricks had been thoroughly cured, dried, and brushed they were painted with various commercial and noncommercial oil-proofing compounds. They were then submerged, with one smoothly troweled untreated brick, under a 20-foot head of 14° B. oil kept, by means of steam coils, at a temperature of 120° F., and allowed to remain in the oil for 120 days. The following results were obtained with the non-commercial coatings:

Acid sludge—brick washed free of acid; not effective.

Hydrochloric acid (1:1)—supposed to fill mouths of pores with silica; not effective; makes concrete more permeable.

Sulphuric acid (1:1)—same result as with hydrochloric acid.

Glue and chromic acid—concrete brick painted twice with glue and then with potassium dichromate solution; exposed to sunlight two days and then submerged in the oil; failure.

Lead paint—paint made of red and white lead, linseed oil, and turpentine was applied to a concrete brick. Paint tended to blister and peel. Oil gained access to the brick through ruptures in the coating. Better than some coating materials, but not very effective.

Condensation products of phenol and formaldehyde—two bricks were painted with this mixture, one of which was baked before being put into the oil. Coatings on both failed on account of cracking.

Sorel cements—preparation consisted of powdered magnesium oxide mixed with some filler, such as powdered silica and magnesium chloride solution. The powder and the liquid were mixed to the consistency of thick paint and applied with a brush. The coating cracked so badly under the test that it was practically useless.

Perdew goes on to state that the commercial coatings were no more effective than the noncommercial, and that the smoothly troweled untreated brick showed as little penetration as any bricks tested. His report gives the following data regarding "an attempt to decrease the permeability of concrete by precipitating barium sulphate in it as it is being mixed."

Cement: Cowell.

Sand: Unscreened sand, same as was used in the reservoir on section 7-C, Coalinga.

No. 4: Twelve briquets made from sand and cement, 3:1, using 13.75 per cent water. No additions.

No. 5: Eight briquets made from sand and cement, 3:1, using 13.75 per cent water. 0.1 per cent by weight of powdered barium chloride was mixed with the dry cement and sand, and sufficient potassium sulphate dissolved in the mixing water to precipitate all of the barium as insoluble barium sulphate.

No. 6: Eight briquets made with sand and cement, 3:1, using 13.75 per cent water. 0.2 per cent by weight of powdered barium chloride was mixed with dry sand and cement before wetting. Sufficient sulphate ions added to mixing water to precipitate all of barium as sulphate.

No. 7: Eight briquets made from sand and cement, 3:1, using 13.75 per cent water. 0.5 per cent by weight of barium chloride was mixed with the dry sand and cement before mixing with the water, to which had been added enough sulphate ions to precipitate all of the barium as the sulphate.

All briquets were stored under water for 20 days. Then half of each lot was dried in an oven, weighed, and submerged under about a 12-foot head of 14° B. oil, whose temperature was about 120° F. The other half of each lot was placed in a cool, damp place. At the end of 3 days more, all briquets were broken, with the following results:

Data regarding concrete briquets tested for permeability.

[Total age of all briquets, 50 days.]

Lot No.	Average tensile strength of briquets in moist air.	Average tensile strength of briquets in hot oil.	Per cent by weight of oil absorbed.
	<i>Pounds per square inch.</i>	<i>Pounds per square inch.</i>	
4.....	265	325	6.3
5.....	290	280	7.2
6.....	285	280	7.2
7.....	280	280	6.6

It is evident that this method is useless for decreasing the permeability of concrete. In fact, it would seem that it increases it. The tensile strength of the different lots was not overly definite, owing probably to the short duration of the test. It would seem that the precipitation of the barium sulphate, or the resultant formation of potassium chloride, accelerates the hardening of the concrete, based upon the tensile strength of the briquets stored in the moist air. Also, the tensile strength seems to decrease with the increase of barium chloride and potassium sulphate. That the highest tensile strength recorded was that of the No. 4 briquets, which had been under hot oil, bears out these conclusions, and is accounted for by assuming that the heat hastened the hardening of the concrete, while the oil had not had time enough to disintegrate it appreciably.

Practically the same treatment was given to briquets made from Coalinga sand, finely powdered diatomaceous earth from Casmalia, Cal., and cement in the propor-

tion 15:5:2, and it was found that the tensile strength of the briquets was decreased and the permeability was increased.

The same test was also applied to briquets made with Coalinga sand, 1:3, to which was added in the mixing water 0.0041 per cent iron in slightly acid solution, with practically the same results regarding tensile strength and permeability.

The following tests were made on briquets placed in 14° B. oil (about 10-foot head), 120° F., for a period of 22 days. Tests for tensile strength were taken before the briquets were immersed in the oil.

Sodium silicate solution—causes decrease in tensile strength with increase of amount added; and causes increase in permeability with increase of amount added.

Crude oil (4 per cent to 9 per cent additions)—decreases tensile strength and increases permeability.

In conclusion Perdwé states:

The fact is again emphasized that dense concrete is the most impervious to oils of 13° to 18° B., even when the oil is heated to a temperature of 120° F. The penetration of oil through the sides of the bricks that were troweled (the tops of the bricks in the molds), and hence the densest, was the least in every case.

COST OF RESERVOIRS.

The cost of a reservoir such as covered by the foregoing specifications would be 10 to 13 cents per barrel of capacity, dependent on the situation and other governing conditions. On a basis of 11 cents, the cost would be distributed approximately as follows:

Cost of earthwork, cents.....	3.5
Cost of roof, cents.....	3.0
Cost of concrete lining, cents.....	4.5
Total, cents.....	11.0

An unlined earthen reservoir with the same type of roof construction would cost 7 to 9½ cents a barrel, and it is estimated that a concrete-lined reservoir with a concrete roof on concrete roof supports and covered with 2 feet of earth would cost about 30 cents a barrel.

The following figures for labor costs cover the construction of two 750,000-barrel reinforced-concrete-lined reservoirs built at Bakersfield, Cal., during the winter and spring of 1913-14:

Labor costs for two concrete oil reservoirs at Bakersfield, Cal.

Earthwork:

Excavating for embankment, per yard.....	\$0.22
Lining inner slopes with selected material, per yard.....	.51
Finishing floor, per square foot.....	.005
Excavating for pier footings, trenches, etc., per yard.....	.70
Trimming slopes, per square foot.....	.012

Roof:

Hauling lumber from cars (½ mile), per M.....	1.19
Framing lumber for roof, per M.....	1.60
Erecting roof, per M.....	3.80
Sawing sheathing, per M.....	1.35

Roofing:

Laying roofing paper, per square.....	\$0. 12
Hauling roofing gravel from cars ($\frac{1}{2}$ mile), per ton.....	. 25
Placing asphalt and gravel coating, per square.....	. 32

Concrete lining:

Hauling cement from cars ($\frac{1}{2}$ mile), per ton.....	. 54
Hauling sand from creek bed (2 miles), per yard.....	. 86
Hauling rock ($\frac{1}{2}$ mile from cars), per yard.....	. 50
Laying reinforcing metal on slope, per square.....	. 16
Laying reinforcing metal on floor, per square.....	. 08
Pouring concrete piers, per yard.....	^a 4. 63
Pouring concrete floor, per yard.....	^a 2. 51
Pouring concrete slope, per yard.....	^a 3. 46

The figures given are based on the following conditions:

Situation of reservoir, half mile from railroad.

Formation of soil, light sandy clay.

Excavators used, wheel and "fresno" scrapers.

Hours worked a day, 9.

Wage paid laborers, \$2.50 a day.

Wage paid carpenters, \$3.50 a day.

Wage paid concrete laborers, \$2.75 a day.

Wage paid concrete finishers, \$4.50 a day.

Wage paid foremen, \$6 a day.

LIFE OF RESERVOIRS AND STEEL TANKS.

A properly constructed concrete-lined reservoir with concrete roof would last for an indefinite period. The life of the modern steel tank is variously estimated. However, the consensus of opinion among the majority of oil men seems to be that a commercial steel tank such as is in use to-day, if placed on a carefully constructed foundation, and if properly maintained, should last, with the exception of the roof, for 35 to 40 years. The roof, if of wood, covered with roofing paper, would of course require repeated repairs during this period to keep it waterproof and, even though it were constructed with steel, parts of it might need to be replaced three or four times by reason of deterioration from light hydrocarbon gases and sulphur fumes.

Several oil tanks examined by the writer have been in use for 20 to 25 years, and their shells are to all appearances in almost perfect condition. One tank at the Standard Oil Co. refinery, Baltimore, Md., of 30,000-barrel capacity, has been in continual service for more than 35 years. This is a wrought-iron tank made from plates much lighter than those used at the present time for a tank of this capacity. The rivet spacing is also greater than is used in modern practice, which means that the tank was not designed with what is considered to-day an adequate factor of safety. For this reason for several years past

^a Including cost of rock, at \$1.60 per ton. All material except sand and gravel was furnished by the owner at the Southern Pacific R. R. one-half mile distant from the work.

it has been carried only about two-thirds full, and, so the superintendent states, will be cut down and replaced in the near future. The roof has been replaced several times, but the shell so far as can be seen is sound and in good condition.

LOSSES IN STORAGE.

BY SEEPAGE.

Oil losses by seepage from steel tanks and from well-constructed concrete-lined reservoirs can be considered practically nil. From unlined earthen reservoirs, however, seepage losses may be very large. It is difficult to determine just what these losses are for the reason that most of such reservoirs, as previously stated, are used as emergency containers; the oil put into them coming unmeasured from flowing wells.

However, there is a record of a 500,000-barrel unlined reservoir in the Kern River field, Cal., that had to be abandoned on account of the excessive seepage losses. Although the reservoir was in use only a short time, pits dug subsequently in the bottom disclosed that the oil had already penetrated for a depth of more than 20 feet.

Another company in the same field found that its losses from both evaporation and seepage from heavy oil of 14° to 16° B. stored in a 1,000,000-barrel reservoir over a period of six years, when the reservoir was kept approximately full, averaged 0.58 per cent a month, or 6.96 per cent a year. After the reservoir had been lined with concrete the losses were reduced to approximately 0.176 per cent a month, or 2.112 per cent a year. Assuming that the losses by evaporation were the same for the lined as for the unlined reservoir, which was practically the case, as oil was constantly being put into and withdrawn from the reservoir under both conditions, the saving of oil due to the lining was 4.85 per cent per year. In other words, if the reservoir were kept full the yearly saving at the present market price of oil (about \$1.00) would amount to \$48,500 a year, which, placing the cost of lining at 5 cents per barrel, would pay for that lining in a little more than a year's time.

LOSSES BY EVAPORATION.

If we knew definitely the volume of useful hydrocarbon products that "vanish into thin air" from the wells, the transportation systems, the storage farms, and the refineries of the United States in one single year's time we might well be staggered by the size of the figures. To form some realization of their gigantic proportions one needs only to stand in the vicinity of a flowing well newly brought in, and witness the volumes of gases rising like exaggerated heat waves from the well itself, from the flow tanks in which the oil is being collected, from the sump into which it has overflowed, and from

every surface exposed to the atmosphere. The greatest unmeasured loss, of course, takes place in the vicinity of the well. Nevertheless, this loss continues in a large measure, especially as regards light oils, through the gathering systems, the transportation systems, and the receiving tanks at the refineries, and even from oil of low gravity there is a continual stream of the light hydrocarbons escaping from its surface so long as it remains in storage.

The following data from Port Arthur, Tex., give a comparison of the losses in a wooden-roof tank and in an all-steel tank with tight roof, having one central vent pipe leading the escaping gases to a point outside the fire levee.

Comparative losses of oil from a wooden-roof tank and from a steel-roof tank.

Kind of tank.	Date.	Gravity of oil in tank.	Depth of oil in tank.	Loss.		Time in storage.	Percentage of loss.	Percentage of loss in a year.
				Inches.	Barrels.			
	1915.	°B.	Fl. in.			Mo. days.		
Wooden-roof.....	May 12	55.9	28 11	11½	1,759	1 10	3.39	30.5
	June 22	55.2	27 11½					
Steel-roof.....	May 5	54.7	29 3½	2½	363	1 17	.687	5.32
	June 22	54.6	29 1½					

The highest temperature recorded at Port Arthur between May 5 and June 22, 1915, was 100° F.

Another Texas company found, from "a record of the evaporation of naphtha stored in a wooden-roof tank and in a steel-roof tank for a period of six weeks, that the loss from the wooden-roof tank was 3.1 per cent, while the loss from the all-steel tank was 0.42 per cent." On this basis the annual loss from the wooden-roof tank would be 25.20 per cent, and from the all-steel tank 3.40 per cent, or a difference in favor of all-steel construction of 21.80 per cent. With gasoline at, say, 15 cents a gallon at the refinery this would amount to \$75,500 a year in a 55,000-barrel tank, indicating that it is the height of folly to attempt to store gasoline even temporarily in a wooden-roof tank.

The following information covers tank farms in Oklahoma and Kansas, the oil in the tanks having remained practically undistributed after the original filling.

Comparative losses from wooden-roof a tanks in different districts.

Situation of tank.	Date filled.	Volume of oil.	Dates of adding oil.	Volume of oil added.	Total volume of oil put in tank.	Date of latest observation.	Good oil in tank.	Difference.	Sludge.	Loss by shrinkage (evaporation).	Average yearly loss by evaporation.		Average age of sludge settling during whole period.	Grav-ity of oil at time of latest obser-vation.
											Period.	Per cent.		
Ramona, Okla...	July, 1905	35,568.09	{Mar., 1908 Jan., 1914	Barrels. 1,734.07 1,455.93	{38,758.09 }	Nov. 1, 1916	Barrels. 34,153.56	4,004.53	1,112.06	3,492.47	July, 1905, to March, 1908... March, 1908, to January, 1914... January, 1914, to November, 1916.	1.84 .71 .30	Per ct. 0.26	° B. 32.9
Jenks, Okla....	Apr., 1907	35,475.75	{Mar., 1909 Apr., 1914	{1,591.57 1,644.67	{38,711.90 }	do.....	32,865.39	5,846.60	2,233.17	3,613.43	{April, 1907, to March, 1909... March, 1909, to April, 1914... April, 1914, to December, 1916.	2.35 .92 .40	.60	b 36.9
Caney, Kans.....	Jan., 1905	35,473.02	.....	.....	.....	Sept. 1, 1907	c 34,024.34	1,448.68	951.46	497.22	January, 1905, to September, 1907.	.48	1.02	33.5
Neodesha, Kans.	Jan., 1904	34,540.05	{Feb., 1906 Jan., 1909	{926.85 731.39	{36,198.20 }	Sept. 1, 1910	32,761.19	3,437.10	1,386.19	2,080.91	{January, 1904, to February, 1906. February, 1906, to January, 1909. January, 1909, to June, 1911.	1.29 .73 .47	.57	d 31.3

^a Wooden roof of each tank was covered with roofing paper and sheet iron.^b Gravity on Sept. 1, 1907.^c Volume on Sept. 1, 1907.
^d Gravity on Sept. 1, 1905.

A report on ten 55,000-barrel tanks, with construction similar to that of the tanks represented in the foregoing table, stored with Cushing oil in the Cushing field, showed the following loss by evaporation:

Gross stock Nov. 1, 1915.....	540, 869. 11 barrels of 39.7° B. oil
Gross stock Sept. 1, 1916.....	537, 530. 77 barrels of 39.1° B. oil
Shrinkage.....	3, 338. 34 barrels
Yearly loss by shrinkage (evaporation), 0.62 per cent.	

Two tanks of Healdton oil stored at Fort Worth, Tex., showed the following results:

Shrinkage in one year of Healdton oil in two tanks at Fort Worth, Tex.

Tank No.	Gross stock Sept. 1, 1915.	Gross stock Sept. 1, 1916.	Shrinkage.	Sludge Sept. 1, 1915.	Sludge Sept. 1, 1916.	Increase in sludge.	Yearly loss by shrinkage (evapora- tion).	Yearly settle- ment of sludge.
	<i>Barrels.</i>	<i>Barrels.</i>	<i>Barrels.</i>	<i>Barrels.</i>	<i>Barrels.</i>	<i>Barrels.</i>	<i>Per cent.</i>	<i>Per cent.</i>
136 ^a	^b 53, 175. 50	^c 53, 044. 20	131. 30	435. 26	739. 57	304. 31	0. 25	0. 57
127.....	^d 53, 616. 60	^e 53, 091. 13	525. 47	366. 98	469. 79	102. 81	. 98	. 19

^a This oil was allowed to stand in earthen sumps for a considerable time before being stored; hence the comparatively small loss by evaporation.

^b Gravity of oil, 28.6° B.

^c Gravity of oil, 28.1° B.

^d Gravity of oil, 28.4° B.

^e Gravity of oil, 27.6° B.

A Pittsburgh, Pa., refinery furnishes data regarding steel tanks of 55,000-barrel and 37,000-barrel capacity, having wooden roofs covered with two-ply roofing paper and over that 22-gage sheet iron. They were used for the storage of Pennsylvania crudes, the results being as follows:

Data regarding evaporation losses in two Pittsburgh, Pa., tanks.

55,000-BARREL TANK.

Date of observation.	Gravity of oil.	Oil in tank.	Remarks.
Sept. 3, 1914.....	°B. 44. 0	<i>Barrels.</i> 54, 036. 12	Pennsylvania crude.
Aug. 13, 1916.....	43. 5	53, 038. 33	
Loss.....	. 5	997. 79	Loss for period, 1.84 per cent, or for a year on same basis, 0.95 per cent.

37,000-BARREL TANK.

June 19, 1914.....	44. 5	36, 068. 51	Pennsylvania crude.
May 1, 1916.....	43. 5	33, 929. 66	
Loss.....	1. 0	2, 138. 85	Loss for period, 5.93 per cent, or for a year on same basis, 3.18 per cent.

Eight new 37,500-barrel steel tanks, having wooden roofs covered with tar paper, over which was sheet iron, were filled with Illinois crude of an average gravity of 33.1° B. The oil was allowed to remain in storage for a period of four years, showing the following results:

Evaporation losses from eight wooden-roof steel tanks filled with Illinois crude.

Period.	Average gravity.	Average loss in gravity.		Average loss in fluid.	
		° B.	Per cent.	Barrels per tank.	Per cent.
When filled.....	33.13				
First year.....	32.22	0.91	2.75	1,007	2.766
Second year.....	31.77	.45	1.39	476	1.308
Third year.....	31.35	.42	1.32	344	.944
Fourth year.....	31.24	.11	.35	215	.588
Total, four years.....		1.89	5.81	2,042	5.606
Average per year.....		.47	1.45	510	1.402

Data from a Middle-West corporation that handles large quantities of crude petroleum and operates extensively in Texas and Oklahoma show that its oil is kept moving so constantly that exact figures on evaporation losses can not be given, but they are believed to be approximately as follows:

Evaporation losses from Texas and Oklahoma crudes.

Grade of oil.	Gravity, ° B.	Annual loss, per cent.
Distillate.....	43 to 50	2.0
North Texas and north Louisiana crudes (light).....	30 to 40	1.5
South Texas and south Louisiana crudes (heavy).....	18 to 25	.7
Oklahoma crude.....	30 to 38	1.0
Oklahoma crude.....	38 to 41	2.5

The following tabulation, compiled by a California company, shows the losses from fresh oils stored for short periods of time while on the way to the refinery or to market. The tanks in which the oil was placed had wooden roofs, some of which were covered with sheet iron. The length of time during which the oil remained quiescent—that is, without additions or withdrawals—ranged from 5 to 30 days. If the time was less than 30 days the amount shown in the column headed “Loss for 30 Days” was computed on the basis of the total loss during the quiescent period. The tanks under observation were in various fields and the oils ranged in gravity from 13.4° to 28.5° B. Temperature readings were taken three times a day—at 7 a. m., at noon, and at 5 p. m., the average temperature shown being the average of these readings for the period.

The average loss per month varied from 0.06 per cent for the heavy oils to 2.5 per cent for light oils, and the loss per year, based on the monthly loss, varied from 0.72 to 30.07 per cent. The yearly loss, however, is obviously too high, as the monthly evaporation would not remain a constant quantity throughout the year, but would decrease somewhat from month to month.

TABLE 4.—*Loss of oil by evaporation from 13 tanks in California.*

[Capacity of each tank, 55,000 barrels, except as otherwise noted.]

TANK 1, LOST HILLS FIELD.

Month.	Average temperature of oil in tank.	Barrels stored.	Number of days.	Total loss.	Loss for 30 days.	Average per cent of loss on amount stored per month.	Average gravity at 60° F.	
1913.								
August.....	° F.	53,300	11	Barrels.	Barrels.	.....	° B.	Record of no value.
September.....	81	49,200	9	191	520	.....	22.9	Temperature not given.
October.....	76	49,200	10	114	380	.....	23.2	Record of no value.
November.....	62	53,000	10	230	690	.....	23.8	
December.....								
1914.								
January.....	63	35,000	11	115	312	.....	23.8	Do.
February.....	63					.....	23.9	
1916.								
January.....	58	5,500	19	76	120	.....	24.6	
February.....	62	10,000	15	76	152	.....	25.7	
March.....	68	9,800	20	114	171	.....	25.5	
April.....	76	8,400	10	76	228	.....	25.4	
May.....	82	48,000	10	115	345	.....	25.7	
June.....						.....		Do.
July.....	92	46,000	10	191	382	.....	26.6	
August.....	94	34,300	17	76	207	.....	27.5	
September.....	90	35,900	17	305	537	.....	27.8	Do.
October.....						.....		
November.....	66	49,200	9	76	253	.....	26.6	
Total.....		455,600		1,755	4,297	0.943		Loss per year, 11.32 per cent.

TANK 2, LOST HILLS FIELD.

1913.								
August.....	98	52,200	22	173	236	.....	23.0	
September.....		10,200	12	192	480	.....	23.8	
October.....	83	52,800	13	75	174	.....	23.4	
November.....	77	54,000	13	340	784	.....	22.7	Looks excessive.

December.....	62	52,000	10	76	228	23.4	Record of no value.
1914.							
January.....							
February.....	61	53,000	10	75½	225	23.1	
1916.							
January.....	56	47,000	9	38	127	24.4	
February.....	60	5,500	24	115	144	24.8	
March.....	66	27,600	18	536	891	24.3	
April.....	76	6,600	30	454	454	23.3	
May.....	80	9,500	11	77	210	25.1	
June.....	88	9,400	14	153	328	25.5	
July.....	92	7,700	12	191	477	26.6	
August.....							Do.
September.....	90	37,500	7	115	492	27.9	
October.....							Do.
November.....	70	51,300	9	153	510		
Total.....		476,300		2,703	5,760	1.209	Loss per year, 14.51 per cent.

TANK 3, LOST HILLS FIELD.

1913.							Record of no value.
August.....	96½	53,500	11	170	463	24.1	
September.....							
October.....	78	49,800	7	57	240	23.4	
November.....	74	54,080	7	228	977	23.3	
December.....							Do.
1914.							
January.....	64	53,000	7	151	648	23.4	
February.....		54,000	16	226	420	24.8	
1916.							
January.....							Do.
February.....	64	10,500	9	76	253	25.7	
March.....							Do.
April.....	76	49,600	13	76	176	25.6	
May.....							Do.
June.....							Do.
July.....	92	13,100	17	191	337	25.9	
August.....	94	9,600	7	38	163	27.1	
September.....	90	10,700	8	115	432	27.2	
October.....							
November.....	76	52,600	13	75	173	27.4	
Total.....		410,400		1,403	4,282	1.043	Loss per year, 12.52 per cent.

TABLE 4.—*Loss of oil by evaporation from 13 tanks in California—Continued.*

TANK 4, LOST HILLS FIELD.

Month.	Average temperature of oil in tank.	Barrels stored.	Number of days.	Total loss.	Loss for 30 days.	Average per cent of loss on amount stored per month.	Average gravity at 60° F.	
1913.	° F.			Barrels.	Barrels.		° B.	Record of no value.
August.....	.....	54,200	5	95½	570	.....	22.8	
September.....	.....	11,500	21	286	409	.....	22.4	
October.....	79	.....	.....	.....	.....	.....	.....	Do.
November.....	64	54,000	10	226	678	.....	23.5	
December.....	.....	.....	.....	.....	.....	.....	.....	
1914.	.....	53,000	13	151	378	.....	23.4	
January.....	63	54,000	13	114	270	.....	23.2	
February.....	.....	.....	.....	.....	.....	.....	.....	
1916.	.....	12,900	11	38	104	.....	23.4	Do.
January.....	56	.....	.....	.....	.....	.....	.....	
February.....	.....	9,300	11	76	207	.....	25.0	
March.....	66	49,900	8	76	285	.....	25.3	
April.....	78	11,300	8	76	285	.....	23.7	
May.....	80	11,300	13	153	333	.....	23.8	
June.....	88	11,000	13	153	333	.....	23.8	
July.....	94	5,600	11	38	104	.....	26.9	
August.....	94	37,300	7	76	326	.....	27.4	
September.....	88	11,400	7	38	163	.....	27.6	
October.....	76	11,400	8	76	285	.....	27.8	
November.....	66	50,100	.....	.....	.....	.....	.....	
Total.....	.....	439,900	.....	1,672	4,770	1.162	.....	Loss per year, 13.94 per cent.

TANK 5, LOST HILLS FIELD.

1913.	.....	51,500	16	244	458	.....	23.4	
August.....	98	52,000	7	150	643	.....	23.2	
September.....	.....	33,700	19	249	403	.....	22.9	
October.....	82	50,500	22	553	753	.....	22.8	
November.....	76	53,000	31	188	180	.....	23.0	
December.....	60	.....	.....	.....	.....	.....	.....	

1914.					
	January.....	60	59,000	11	114
	February.....	63	53,000	10	75
1916.					
	January.....	54	4,200	30	38
	February.....	58	4,200	30	76
	March.....	64	4,100	30	115
	April.....	76	4,000	30	38
	May.....	80	3,900	30	76
	June.....	86	3,900	30	153
	July.....	90	3,700	30	115
	August.....	94	3,600	30	76
	September.....	88	3,500	30	115
	October.....	74	3,400	30	76
	November.....	66	3,300	30	76
	Total.....		385,500		2,527
	Total, tanks 1 to 5.....		2,167,700		10,120
					23,112
					1,039
					1,066
					23.0
					22.7
					23.1
					23.0
					22.8
					22.5
					22.3
					21.9
					21.2
					19.5
					19.0
					18.7
					18.1
					Loss per year, 12.47 per cent.
					Total average loss per year, 12.79 per cent.

TANK 6, MIDWAY FIELD.

1914.							
January.....	60	38,800	8	57	214	27.2	
May.....	81	49,200	9	233	777	26.3	
Total.....		88,000		290	991	1.126	Loss per year, 13.51 per cent.

TANK 7, MIDWAY FIELD.

1914.							
January.....	58	53,000	10	295	885	.....	28.1
February.....	62	50,100	12	57	143	.....	28.5
Total.....	.....	103,100	.....	352	1,028	.997	.....
Loss per year, 11.96 per cent.							.....

TABLE 4.—Loss of oil by evaporation from 13 tanks in California—Continued.

TANK 8,^a MIDWAY FIELD.

Month.	Average temperature of oil in tank.	Barrels stored.	Number of days.	Total loss.	Loss for 30 days.	Average per cent of loss on amount stored per month.	Average gravity at 60° F.
1913.	° F.			<i>Barrels.</i>	<i>Barrels.</i>		° B.
July.....	.....	35,300	18	931	1,551	.....	23.9
August.....	.....	34,000	19	400	631	.....	27.4
1914.							
February.....	62	35,000	13	63	145	.....	28.5
May.....	70	33,400	7	265	1,136	.....	26.0
Total.....	.....	137,700	.....	1,659	3,463	2.506	.....
							Loss per year, 30.07 per cent.

Looks excessive.

Loss per year, 30.07 per cent.

TANK 9,^a MIDWAY FIELD.

1913.							
August.....	.....	35,100	21	426	609	.....	25.8
October.....	74	34,700	8	120	450	.....	28.4
1914.							
April.....	71	36,100	16	413	775	.....	26.7
May.....	76	32,200	15	239	478	.....	26.1
Total.....	.....	138,100	.....	1,198	2,312	1.673	.....
							Loss per year, 20.08 per cent.

Loss per year, 20.08 per cent.

TANK 10,^a MIDWAY FIELD.

1913.							
October.....	82	35,300	9	289	960	.....	27.5
1914.							
May.....	89	33,700	7	114	489	.....	25.9
Total.....	.....	69,000	.....	403	1,449	2.100	.....
Total, tanks 6 to 10.....	.....	535,900	.....	3,902	9,243	1.725	.....
							Loss per year, 25.20 per cent.
							Total average loss per year, 20.70 per cent.

Loss per year, 25.20 per cent.

Total average loss per year, 20.70 per cent.

TANK 11, AT PUMPING STATION NEAR REFINERY.

1913.	(b)	29,000	84	427	152	0.524	24.0	Loss per year, 6.29 per cent.
August to November.....								

TANK 12,^a KERN RIVER FIELD.

1912.								
October.....		36,000	31	48			13.4	
November.....		36,000	30	9				
December.....		36,000	31	8				
1913.								
January.....		36,000	31	13				
February.....		36,000	29	11				
Average per month.....		36,000		89	18	.05		Loss per year, 0.6 per cent.

TANK 13,^a KERN RIVER FIELD.

1912.								
October.....		36,000	31	28			13.4	
November.....		36,000	30	21				
December.....		36,000	31	27				
1913.								
January.....		36,000	31	9				
Average per month.....		36,000		85	21	.06		Loss per year, 0.72 per cent.

^a Capacity of tank, 37,000 barrels:^b Average temperature of oil in tank in August, 94°; in November, 70°.

A California company reports that 18° B. asphaltum-base oil placed in storage in a concrete-lined reservoir with wooden roof showed a loss of 5.52 per cent after a year's time, and that during this period the gravity of the oil was reduced to 15.5° B. So far as is known all of this loss was by evaporation. The same company goes on to say that "Fuel oil of more than 14° B. should not be stored in reservoirs. The evaporation and leakage increase in proportion to the rise in gravity. Our experience has been with concrete-lined reservoirs in the Kern field (California) with gravity of oil ranging about 14° B.; out of eight lined reservoirs our smallest average loss in one reservoir was 0.35 per cent a year; our greatest loss in one of these reservoirs for the same period was 1.92 per cent, and the average loss in all the reservoirs for the year was 1.056 per cent."

These reservoirs have wooden roofs covered with roofing paper, and similar in construction to the roof described in the specifications.

Actual figures taken by the writer from the oil-storage reports of another California company show the following yearly losses from three concrete-lined reservoirs.

Evaporation losses from three concrete-lined tanks in California.

Quiescent period.	Capacity of reservoir.	Depth of oil (approximate).	Gravity of oil.	Per cent loss for period.	Per cent loss, same basis, per year.
	<i>Barrels.</i>	<i>Ft. in.</i>	<i>°B.</i>		
Sept. 1, 1915, to Aug. 1, 1916.....	750,000	21 9	14	0.542	0.59
Do.....	750,000	21 10	14	.382	.42
Do.....	500,000	19 10	14	.630	.69

These reservoirs have wooden roofs, and all of the losses indicated so far as is known were from evaporation.

Table 5 following, comprising a compilation of foregoing data, would indicate the average losses by evaporation from various gravities of distillates and crudes. However, the figures can not be taken as a basis on which to estimate closely future losses, for the reason that although most of them seem fairly reliable, it must be remembered that petroleum is an extremely complex mixture of hydrocarbon combinations having various gravities and various boiling points. A crude oil, for instance, with a gravity of 40° B. may be composed of some of the heavier hydrocarbons and some of the very light hydrocarbons, whereas another oil, with the same gravity, 40° B., may be composed of hydrocarbon compounds varying little from that gravity. The first oil would lose rapidly by evaporation when placed in storage, whereas the latter, although originally of the same gravity, would evaporate much more slowly.

The summary does serve to show that there is a considerable loss from all grades of oil when placed in storage, and that the evaporation from some grades of fresh oil is alarmingly large. Although the figures are admittedly incomplete, as the majority of operators have no reliable information as to exact losses from evaporation, it is hoped that publication of the figures may assist to stimulate producers and refiners generally to a more systematic effort toward determining the real magnitude of such losses. When this is done the writer believes the inevitable result will be much more definite and systematic efforts toward overcoming these losses than are at present exercised.

TABLE 5.—*Summary of losses of oil in storage by evaporation.*

Gravity of oil.	Type of container.	Average monthly loss.	Average yearly loss.	Remarks.
^{° B.}		<i>Per cent.</i>	<i>Per cent.</i>	
60 to 55 distillate.....	Wooden-roof tank, paper top.....	.....	27.8	Plain top; no water seal.
Do.....	All-steel tank.....	.....	4.36	Water topped and lagged.
Do.....	.....	.....	3.76	
50 to 43 distillate.....	.....	.....	2.00	
44 to 41.....	Wooden-roof tank, sheet-iron top.....	.....	2.02	
41 to 38.....	All-steel tank.....	.....	2.50	Pennsylvania crude.
38 to 30 crude.....	.....	.....	1.00	Oklahoma crudes.
Do.....	.....	.....	1.61	Texas and Louisiana crudes.
33 crude.....	Wooden-roof tank, sheet-iron top.....	.....	1.40	Kansas and Oklahoma crudes.
25 to 18 crude.....	.....	.....	.70	Illinois crude.
28 to 22 crude.....	.....	.....	.....	Texas and Louisiana crudes.
18 crude.....	Wooden-roof tank, paper top.....	1.30	5.52	Fresh California crudes.
16 to 14 crude.....	Unlined reservoir, wooden roof.....	.....	6.96	Do.
14 crude.....	Concrete-lined reservoir, wooden roof.....	.....	.95	Do.
13.4 crude.....	Wooden-roof tank, paper top.....	.....	.66	Do.

DIFFICULTIES IN OBTAINING RELIABLE DATA REGARDING EVAPORATION LOSSES.

In dealing with large bodies of oil as contained in reservoirs of 750,000-barrel to 1,000,000-barrel capacity the "personal equation" of the gager may make a considerable discrepancy in results. There is also the likelihood of applying an incorrect coefficient of expansion^a in making the necessary volumetric corrections occasioned by reason of the oil having a temperature above or below the normal. For exact work the coefficient of expansion for each oil in question should be determined. Two oils of similar physical characteristics seldom have the same coefficient of expansion. For instance, it is the custom of many companies in handling low-gravity oil to subtract from the volume, if the indicated temperature is above 60° F., and to add to it if below 60° F., an amount equal to 1 per cent of the indicated volume for every 20 degrees variance from the normal temperature, which is another way of saying that a coefficient of expansion of 0.0005 is applied. Suppose, however, that the actual coefficient of expansion was 0.0004 (or such that the applied correction would be 1 per cent for every 25 degrees variance in temperature), and that the reservoir under consideration is of 1,000,000-barrel capacity having the variance in temperature 10 degrees; the computed figures would then be in error by 1,000 barrels.

DEVICES USED FOR LESSENING EVAPORATION LOSSES.

Why does oil evaporate? The accepted theory regarding the constitution of matter and the nature of heat assumes that all liquids are composed of molecules which are held together by mutual attraction. When a liquid is warmed above -273°C . the molecules are in constant and rapid motion, and, as a result there are spaces between them. As heat is applied to the liquid the molecules move more and more rapidly and strike against each other with greater force, separating further against the force of cohesion. Molecules near the surface of the liquid and vibrating rapidly pass out from it. Some are drawn back again into the liquid by cohesion, but some escape into the air above the surface. If the vessel containing the liquid is open, in time all may escape. However, if the vessel is tightly closed the molecules can not escape from it, and even though it be only partly filled with liquid the air above the surface soon becomes so filled with vibrating molecules that the number leaving the surface of the liquid in a given time is just equal to the number going back into it. The air above the liquid is then saturated and evaporation ceases. If the temperature of the liquid in the closed vessel is increased, vaporization again takes place, but ceases as

^a See Crossfield, A. S., The coefficient of expansion of California crude oils and distillates: West. Eng. vol. 6, December, 1915, pp. 229-238.

soon as the air in the vessel above the liquid becomes saturated for that temperature. However, the pressure in the vessel is increased. If the warm saturated air is cooled some of the vapor condenses and returns to the liquid and the pressure is decreased.

Devices for preventing evaporation losses should be designed with two purposes in view—first, to keep the temperature of the oil in the vessel as low as possible, and, second, to make the container as tight as practicable.

WATER-SEAL TOPS.

Perhaps the most common method of decreasing evaporation losses in an oil-storage tank is by the water-seal top, shown in Plate XIX, A. This form of construction is usually applied to small tanks of 1,000-barrel to 5,000-barrel capacity such as run-down tanks in which naphthas and light refined products are received from the tail houses. The construction of the tank is similar to other steel tanks except that it has a flat roof constructed from riveted plate calked and made water-tight, which is placed about 6 inches below the upper edge of the shell. The space inclosed above the plate is then filled with water that can be kept constantly circulating, thus keeping the tank and its contents cool. The tank shown in Plate XIX, A, is also fitted with a relief vent (in the foreground) which permits the escape of gas through a water seal and allows air to be taken in, as when the tank is being emptied, through a swing check valve open to a pressure from without, but closed to pressure from within the tank.

Table 6 following shows the results of tests made with small tanks of 100-barrel capacity, some of which had plain sheet-iron tops and others water tops. Each water-top tank was also protected with a sheathing of 1-inch boards surrounding the sides and the top of the tank and at a distance of about 18 inches from it. The use of these protective devices decreased the losses by evaporation as much as 14 per cent.



A. STORAGE TANK WITH WATER-SEAL TOP.



B. SPRINKLER FOR COOLING TANK.



C. BAFFLE PLATE AROUND EDGE OF ROOF TO DEFLECT WATER FROM SPRINKLER AGAINST SIDE OF TANK. NOTE STEEL STAIRWAY.

TABLE 6.—Results of comparative 30-day tests for losses in plain-top and water-top tanks protected with sheathing.

[Nominal capacity of tanks, 100 barrels; galvanized iron; 9 feet 5½ inches in diameter; 7 feet 10½ inches high 16-gage iron.]

TEST 1.

	Date of test.	Temperature of oil.	Volume in tank.	Corrected gravity.	Losses.		Gravity.
					Barrels.	Per cent.	
Plain-top tank:	1915.	° F.	Barrels.				° B.
Test started.....	Sept. 28	92	92.57	23.4			
Test finished.....	Oct. 27	84	75.02	27.4			
Losses.....					17.55	19	6.0
Water-top tank:							
Test started.....	Sept. 28	86	93.72	33.6			
Test finished.....	Oct. 27	71	90.10	33.3			
Losses.....					3.62	3.86	.3
Saving by use of water top.....					13.93	15.14	5.7

TEST 2.

Plain-top tank:	1915.						
Test started.....	Nov. 17	76	81.43	31.0			
Test finished.....	Dec. 17	54	72.44	26.8			
Losses.....					8.99	11.04	4.2
Water-top tank:							
Test started.....	Nov. 17	71	82.44	30.0			
Test finished.....	Dec. 17	54	82.37	30.0			
Losses.....					.07	.1	.0
Saving by use of water top.....					8.92	10.94	4.2

TEST 3.

Plain-top tank:	1916.						
Test started.....	Aug. 8	90	85.88	29.9			
Test finished.....	Sept. 8	90	73.70	25.7			
Losses.....					12.18	14	4.2
Water-top tank:							
Test started.....	Aug. 8	90	84.66	29.9			
Test finished.....	Sept. 8	78	84.66	29.8			
Losses.....					.0	.0	.10
Saving by use of water top.....					12.18	14	4.1

MEAN TEMPERATURES.

Test 1.—Mean temperatures: 7 a. m., 75.6° F.; 12 m., 101.2° F.; 5 p. m., 80.7° F.; average, 85.8° F. (average temperature not strictly accurate as no midnight temperature was taken).

Test 2.—Mean temperatures: 7 a. m., 47.6° F.; 1 p. m., 62.8° F.; 5 p. m., 60° F.; 12 p. m., 50° F.; average, 55° F.

Test 3.—Mean temperatures: 7 a. m., 90.8° F.; 12 m., 92.5° F.; 5 p. m., 91° F.; 12 p. m., 72.3° F.; average, 86.7° F.

SPRINKLING TANKS WITH WATER.

Plate XIX, *B*, shows a tank-sprinkling device used by a Pennsylvania company. It is made on the principle of a lawn sprinkler and is placed on the roof at the center of the tank. During hot weather the spraying device is kept in constant operation. The water on

leaving the roof is deflected against the sides of the tank by the baffle plate shown in Plate XIX, *C*, so that it passes in a film over practically the whole outside surface of the tank.

GASOMETERS.

Plate IX, *B* (p. 18) shows a type of gasometer in use by the Shell Oil Co. of California for the collection of the light gases. The gasometer is attached to a battery of gasoline-storage tanks of gas-tight construction. Its purpose is to take care of the expansion and contraction, owing to changes in temperature, of the light gases filling the space between the surface of the gasoline and the tops of the tanks. If one tank in the battery is being filled while another is being emptied, the function of the gasometer is also to conserve the gases discharged from the tank being filled. Such gases ordinarily escape into the atmosphere, but the gasometer causes them to be returned to a tank being emptied. There seems no reason why such a system could not be applied to run-down tanks, and the like, a provision being made whereby any surplus gases not taken care of by the gasometer could be drawn off and condensed, or otherwise profitably disposed of.

TILE-ENCASED TANKS.

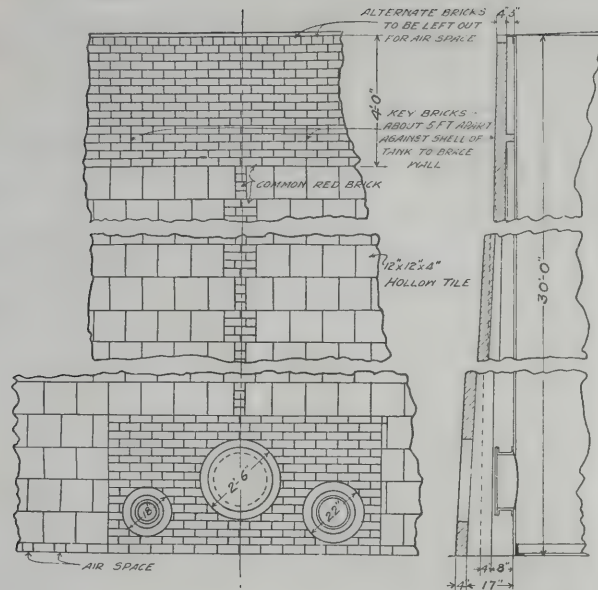
Tile-encased tanks (Pls. IX, *C*, and XX) are also in use. This type of protection, in the writer's opinion, would be much more effective if some type of casing were applied to the roof of the tanks as well as to the sides. The method of protection shown in Plate XX is said by the users to reduce evaporation losses 4 to 6 per cent. The tile used is ordinary hollow building tile such as is used in modern building construction.

BURYING TANKS.

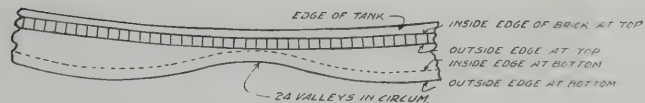
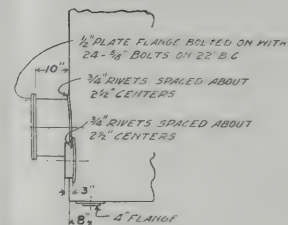
Partly or wholly burying oil tanks in the ground is a common practice among some refiners. However, the ultimate economy is questionable, as depreciation of the shell from soil corrosion may be rapid, and leaks, unless relatively large, are hard to detect and expensive to repair.

CONCRETE TANKS.

Small reinforced-concrete tanks (Pl. XXI, *A*, *B*, and *C*), about 34 feet in diameter by 10 feet high, are being built by several refineries in various parts of Oklahoma. Each of these tanks has a capacity of about 1,500 barrels and is buried in the ground to within 3 or 4 feet of the top. The roof of the tank is 4 inches thick, the walls 8 inches, and the bottom 5 inches. The roof has a slope from the center to the edge of about 1 inch in 4 feet, and the bottom a slope from the side walls to the center where a sump 4 feet in diameter by



DETAIL OF MAN HOLE AND PIPE CONNECTIONS



DETAIL OF TILE CASING

DETAIL OF TILE CASING FOR 55,000-BARREL TANK.

3 feet deep is constructed. A swinging pipe can be lowered into the sump when it is desired to drain the entire contents of the tank.

After the forms inside the tank have been removed from the walls and bottom these surfaces are given one to three coats of neat cement. When this has thoroughly dried, several coats of a commercial oil-proofing paint are applied.

One such tank has been in use by an Oklahoma company for the storage of 42° B. oil, since October, 1916. So far the tank has given complete satisfaction and the erection of additional tanks in the near future is proposed.

The estimated cost of concrete construction for various sizes of tank is as follows:

Estimated cost of various sizes of concrete tanks.

Capacity of tank, barrels.	Cost.	Capacity of tank, barrels.	Cost.
250	\$500	5,000	\$3,900
500	775	10,000	7,500
750	1,000	15,000	10,000
1,500	1,750	35,000	15,500
1,600	2,000	55,000	18,000
2,500	2,600		

In connection with the use of underground concrete tanks for the storage of oil it is interesting to note that the El Paso & Southwestern Railroad Co., at various places along its system, has for the past five years been storing fuel oil of 24° to 38° B. in circular concrete tanks about 12 feet in diameter by 6 feet deep. The bottoms of these tanks are 8 inches thick and the sides 6 inches thick, and each tank is covered by a concrete roof. The proportion of the mix is 1:2:4 and the largest rock 1 inch. The aggregate is thoroughly mixed, and care is taken that when it is placed in the forms it is well tamped and all air bubbles thoroughly worked out so as to insure as dense a concrete as possible.

Tanks that have been in use five years have been examined inside and out but no signs of leakage were discovered. At present the company has 12 such tanks, and their adaptability to oil storage has proved so satisfactory that more are in process of construction. No oil or waterproofing compounds are used.

A local company at San Antonio, Tex., has three such tanks, but of much greater capacity (180,000 to 400,000 gallons) in which oils ranging in gravity from 15° to 30° B. have been stored. One of these tanks has been in use 12 years. It was emptied recently and examined inside and out but no signs of leakage were found. The mix, as for the El Paso tanks, is 1:2:4 and the coarsest aggregate 1-inch rock.

At present a fourth tank is being constructed. This will have a diameter of 61 feet 6 inches, a depth of 18 feet, and a capacity of about 400,000 gallons. The bottom will be 17 inches thick and the sides 2 feet at the bottom tapering to 1 foot at the top; all heavily reinforced with steel rods. No oil-proofing compounds are used in any of these tanks.

A local electric company at St. Helena, Cal., built a rectangular reinforced-concrete tank in 1911. This tank is 16 feet long, 14 feet wide, and $5\frac{1}{2}$ feet deep, having a capacity of approximately 10,000 gallons. The bottom is 20 inches thick and the sides 8 inches at the bottom, tapering to 5 inches at the top. Both the sides and the bottom were reinforced with steel rods. At the time the tank was constructed it was coated inside with a solution of sodium silicate. However, after 18 months of service the coating had become practically useless. The tank at this time was examined inside and outside by digging pits, but as no leakage was found no further attempt at oil proofing was made. Since that time the tank has been continually in service for the storage of oil varying in gravity from 15° to 26° B. The roof of this tank is made of wood covered with roofing paper. As a means of lessening evaporation losses and providing a run-off for rain water, as the wooden roof is practically flat, a second corrugated-iron roof of proper pitch has been constructed about 3 feet above the first roof, allowing free circulation of air between the two.

A refining company at Fort Smith, Ark., has two small rectangular reinforced-concrete tanks, one 10 by 14 by 6 feet, and the other 8 by 10 by 5 feet, which have been successfully used for the storage of oils up to 40° B. for the past seven years. There is nothing unusual in the construction of these tanks except that they were made of carefully selected aggregate well mixed and thoroughly tamped. No oil-proofing materials were used.

A large oil company at Tulsa, Okla., has recently completed a concrete reservoir about 200 feet square by 24 feet deep. The walls of the bottom 12 feet have a slope of about 1 : 1, and are supported by the natural earth backing, whereas the walls for the remaining 12 feet are vertical and backed by the excavated earth. The reservoir has a concrete roof, built on much the same principle as the floor of a modern class A building. The intention is to keep the roof of this reservoir covered by 2 feet or more of water and to allow the water to percolate down through the earth along the outside of the concrete.

The table following shows a list of companies that are using small concrete containers for the storage of oil, also the kind of oil stored, and whether the container has proved satisfactory.



A. EXCAVATING FOR A CONCRETE-LINED TANK.



B. FORMS FOR CONCRETE TANK.



C. COMPLETED TANK.

List of users of concrete tanks for oil storage.

Name of company.	Address.	Approximate size of container.	When installed.	Gravity of oil stored.	Remarks.
Santa Fe R. R.	Various places along system.	<i>Feet.</i>			
Standard Oil Co.	Clearmont, N. J.	25 by 40 by 12.	1910.	Heavy.	Partly satisfactory.
Do.	do.		1914.	Naphtha.	Walls cracked, owing to settlement in foundation. Two old steel tanks lined with concrete. 1:2:4 mixture.
Williamson Milling Co.	Clay Center, Kans.	12 by 20 by 10.	1910.	Heavy.	Inside given coat of water glass. Satisfactory.
Southern Nebraska Power Co.	Superior, Nebr.	10 by 30 by 6.	January, 1917.	do.	Two-foot earth fill over top. Satisfactory.
Ozark Refining Co.	Fort Smith, Ark.	44a by 18.	do.	38° to 40° B., at 60° F.	
Do.	do.		1912.	Average, 30° B.	
Winters Cotton Co.	Winters, Tex.	24a by 12.	1909.	Heavy.	Eight small concrete tanks 150 to 250 barrels each. Satisfactory. Given coating 1:1 cement mortar.
Texas Light & Power Co.	Paris, Tex.		May, 1915.	28° to 30° B.	Satisfactory.
Desert Power & Mill Co.	Millers, Nev.		1907.	Heavy.	Walls 12 inches thick at bottom; 8 inches thick at top.
Houston Light & Power Co.	Houston, Tex.	34 by 11.	January, 1912.	21° to 30° B.	Satisfactory. Satisfactory.
Cotton Seed Oil Co.	Oklahoma City, Okla.	25 by 10.	September, 1908.	Heavy.	145,000 gallons. Satisfactory.
Magnolia Compress Co.	Houston, Tex.	25 by 16 by 8.	May, 1912.	23° B.	Two compartments. Tank was otherwise in good condition and still being used.
Muskogee Refining Co.	Muskogee, Okla.	32 by 11.	December, 1916.	63° B. gasoline.	Satisfactory. Partly satisfactory.
San Antonio Gas & Electric Co.	San Antonio, Tex.	45a by 15.	1905.	14° to 21° B.	Three tanks. Wall 36 inches thick at bottom, tapering to 21 inches at top. Bottom 42 inches. Satisfactory.
Do.	do.	24a by 12.	1912.	24° to 28° B.	Satisfactory.
Do.	do.	46 by 16.	1912.	14° to 21° B.	Do.
Do.	do.		May, 1917.	do.	400,000 gallons. Satisfactory.
Seymour Oil Co.	Seymour, Tex.	45 by 16 by 12.	1906.	Heavy.	1,200 gallons. Satisfactory.
Amudarko Cotton Oil Mill.	Amudarko, Okla.	35 by 16 by 10.	September, 1915.	28° to 28° B.	Satisfactory.
Fairbanks, Morse & Co.	Redot, Wis.	20a by 8.	1916.	Heavy.	Four tanks. Satisfactory.
Aula Gas & Electric Co.	Ada, Okla.		September, 1908.	28° B.	Used for oil until July, 1911; since for water. Satisfactory.
Charles City Gas Co.	Charles City, Iowa.	22a by 10.	1916.	Heavy.	30,000 gallons. Satisfactory.
Shawnee Gas & Electric Co.	Shawnee, Okla.	200 by 200 by 25.	November, 1908.	20° B.	Satisfactory.
Cosden Refining Co.	Tulsa, Okla.	23 by 7.	1910.	25° B.	Partly satisfactory.
Dewey Portland Cement Co.	Dewey, Okla.	43 by 12.	1916.	42° B.	Thoroughly.
Webster Oil & Gasoline Co.	Oilton, Okla.		1909.		Satisfactory. One (16,000 barrels) still in use for hot crude.
Indianola Refining Co.	Oklmulgee, Okla.				Only partly satisfactory. Others failed by settling.

a Diameter.

PAINTING TANKS LIGHT COLORS.

Many oil operators, especially throughout the eastern and the middle western fields, have adopted white or light-colored paints for storage tanks. It is reported that tests have demonstrated that evaporation from tanks painted white averages about 1 to 1½ per cent less than from tanks painted red, and about 2½ per cent less than from tanks painted black. These figures have not been verified, but tests made by the Institute of Industrial Research ^a show that dark-colored paints absorb heat to a considerable degree, and paints presenting a highly glossy surface are less absorptive of thermal rays than those presenting a matte surface.

Experiments were conducted wherein small tanks containing benzine were painted in various colors (gloss finish) and then subjected to the rays of a powerful arc light for 15 minutes. At the end of that period the rise in temperature of the benzine was as follows:

Rise in temperature of benzine stored in tanks of various colors.

Color of paint or covering.	Rise in temperature, ° F.
Tin plate (tank plated with tin).....	19.8
Aluminum paint.....	20.5
White paint.....	22.5
Light-cream paint.....	23.0
Light-pink paint.....	23.7
Light-blue paint.....	24.3
Light-gray paint.....	26.3
Light-green paint.....	26.6
Red iron oxide paint.....	29.7
Dark prussian blue paint.....	36.7
Dark chrome green paint.....	39.9
Black paint.....	54.0

Tin plating and aluminum paint, as will be seen, gave the best results. However, neither of these finishes is practicable for outside work, as iron coated with tin corrodes rapidly, and aluminum paint soon loses its gloss and becomes flaky. The rise in temperature of the benzine in the tank painted black was 31.5° F. greater than the rise in the tank painted white, or 140 per cent. Although results such as obtained by these laboratory experiments could not be expected in actual practice, there is undoubtedly a decided advantage to be gained by painting storage tanks white.

^a Gardner, H. A., The heat-reflecting properties of colors applied to oil and gas storage tanks: Circular 44, Paint Mfg. Assn. of U. S., Educational Bureau, Sci. sec., January, 1917, p. 1.

COMPUTING VOLUME OF TANKS AND RESERVOIRS AND PREPARING GAGE TABLES.

METHODS OF OBTAINING FIELD DATA REGARDING TANKS.

The methods used by the various oil companies in obtaining the data necessary for computing the volumes of oil tanks and reservoirs, and for preparing gage tables are practically the same, differing only in minor details. As regards steel tanks there is much discussion as to just how many circumference measurements are necessary for accurate work. Some companies take only two (for a 6-ring tank), the lower one being at the middle of the second ring and the upper as

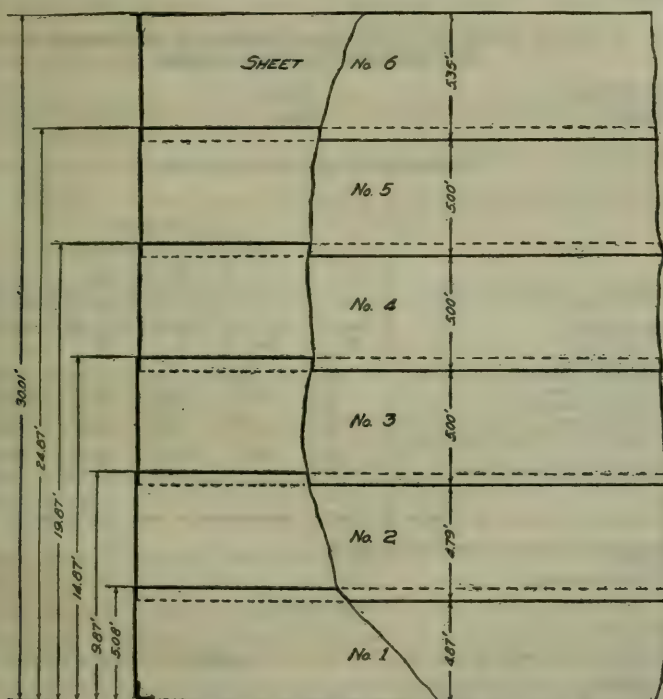


FIGURE 3.—Points between which various measurements for height of sheets apply.

near as practicable to the middle of the top ring. Other companies "strap"^a above each seam, and take one measurement 6 inches below the top of the tank, and one near the bottom just above the bottom row of rivets. However, it has been found that in measuring steel tanks of standard size a surprisingly small variation in results will be obtained if circumference measurements are taken on each ring, or if only the top and bottom rings are measured and the circumference

^a A term in general use among oil operators, originally meaning the girthing of tanks with a measuring tape, but in modern diction includes the whole operation of obtaining the necessary field data for computing the volume of tanks and other fluid receptacles.

of the others computed. On the other hand, tanks on poor foundations causing them to be "out of round" and producing bulging uneven sides may require a large number of measurements to insure accuracy. Although it is difficult to lay down any fixed rules that will apply to all classes of tanks it is believed that the following form of field notes includes sufficient data for reasonably accurate results. A 55,000-barrel tank has been assumed in which the roof supports consist of wooden posts tied together with sway bracing and resting on footing blocks, as this is the most complicated form of construction so far as volumetric computations are concerned. The points between which the various measurements for height of sheets apply are shown in figure 3.

RECORD OF FIELD NOTES SHOWING MEASUREMENTS NECESSARY FOR COMPUTING VOLUMES OF STEEL TANKS.

Location of tank: Party:
Size of tank: Date:

Measurements of tank^a by courses.

Item.	Course No. ^b					
	1	2	3	4	5	6
Circumference, feet.....	360.37	360.17	360.09	^c 360.13	^c 360.17	360.22
Number of sheets, feet.....	26	26	26	26	26	26
Lap of vertical seam, feet.....	.19	.19	.19	.19	.17	.12
Lap of horizontal seam, feet.....	.21	.21	.21	.21	.21	.....
Horizontal segment, feet.....	2.50	2.00	2.00	^c 1.58	^c 1.17	.67
Thickness of sheet, inches.....	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
Thickness of sheet, feet.....	.05	.04	.03	.02	.02	.02
Bottom of tank to top of sheet (outside), feet.....	5.08	9.87	14.87	19.87	24.87	^d 30.01
Edge to edge of sheet (inside), feet.....	4.87	4.79	5.00	5.00	5.00	^d 5.35

^a Bottom angle iron, $\frac{1}{2}$ inch by 4 inches by 4 inches; measurements taken approximately in center of courses.

^b Courses numbered from bottom of tank upward.

^c Calculated.

^d Top of top angle iron.

DEADWOOD.

Footing blocks:

Outside circle posts, 22 pieces, 2 inches by 8 inches by 2 feet. Bottom of tank to 2 inches.

Third circle posts, 12 pieces, 2 inches by 8 inches by 2 feet. Bottom of tank to 2 inches.

Third circle posts, 2 pieces, 2 inches by 8 inches by 2 feet. Bottom of tank from 2 inches to 4 inches.

Second circle posts, 10 pieces, 2 inches by 8 inches by 2 feet. Bottom of tank to 2 inches.

Center circle posts, 2 pieces, 2 inches by 8 inches by 12 $\frac{1}{2}$ feet. Bottom of tank to 2 inches.

Center circle posts, 2 pieces, 2 inches by 8 inches by 12 $\frac{1}{2}$ feet. Bottom of tank, from 2 inches to 4 inches.

Bottom ties:

Outside circle posts, 2 pieces, 2 inches by 8 inches by 15 feet 4 inches. From 4 inches to 12 inches.

Bottom ties—Continued.

Third circle posts, 1 piece, 2 inches by 8 inches by 16 feet 8 inches. From 6 inches to 14 inches.

Second circle posts, 2 pieces, 2 inches by 8 inches by 15 feet. From 2 inches to 10 inches.

Swing-pipe rest:

1 piece, 1½ inches by 8 inches by 13 feet. From 12 inches to 20 inches.

2 pieces, 1½ inches by 8 inches by 20 inches. From 2 inches to 20 inches.

2 pieces, 2 inches by 8 inches by 24 inches. From bottom of tank to 24 inches.

2 pieces, 1½ inches by 8 inches by 20 inches. From 23 inches to 24½ inches.

Sway bracing:

Outside circle posts, 48 pieces, 1 inch by 6 inches by 24 feet. From 3 feet to 21 feet 8 inches.

Third circle posts, 30 pieces, 1 inch by 6 inches by 23 feet. From 3 feet to 20 feet 5 inches.

Second circle posts, 20 pieces, 1 inch by 6 inches by 22 feet. From 3 feet to 22 feet.

Center circle posts, 4 pieces, 1 inch by 6 inches by 18 feet 6 inches. From 4 inches to 14 feet.

Center circle posts, 4 pieces, 1 inch by 6 inches by 18 feet. From 4 inches to 13 feet 5 inches.

Center circle posts, 2 pieces, 2 inches by 8 inches by 14 feet 6 inches. From 13 feet 5 inches to 14 feet 1 inch.

Girders:

Outside circle posts, 24 pieces, 5 inches by 12 inches by 15 feet. From 28 feet 6 inches to 29 feet 6 inches.

Knee braces:

Outside circle posts, 12 pieces, 2 inches by 8 inches by 6 feet. From 24 feet 5 inches to 28 feet 6 inches.

Third circle posts, 16 pieces, 2 inches by 8 inches by 6 feet. From 27 feet 4 inches to top (45°).

Second circle posts, 10 pieces, 2 inches by 8 inches by 6 feet. From 28 feet 6 inches to top (45°).

Posts:

Outside circle, 24 pieces, 6 inches by 6 inches. From 4 inches to 28 feet 4 inches.

Third circle, 16 pieces, 6 inches by 6 inches. From 4 inches to top.

Second circle, 10 pieces, 6 inches by 6 inches. From 2 inches to top.

Center circle, 4 pieces, 6 inches by 6 inches. From 4 inches to top.

Rafters: 120, 2 inches by 8 inches.

Distance from bottom of tank to bottom of rafter at center of tank, 36 feet 6 inches.

Top of rafter at shell flush with top of top angle iron.

Manhole, 23½ inches in diameter by 6 inches deep. Bottom, 20 inches above bottom tank.

METHODS OF MEASURING.

The outside measurements should be taken in feet and hundredths, the most convenient form in which to have the data for computations. Measurements of deadwood, by which is meant all material inside the tank that displaces oil, such as roof supports, blocking, steam coils, and water draw-off pipes, are usually more conveniently taken in feet and inches, as the parts mentioned usually consist of standard-sized timbers and pipes.

The circumference measurements are taken as nearly as possible in the center of each course with the exception of courses 4 and 5 (count-

ing from the bottom upward), which can be more accurately calculated by interpolating between the girths of courses 3 and 6 than by actual measurement. The circumference of the top course is taken by reaching down over the eaves of the tank, the tapeman lying face down on the roof.

If possible, inside measurements should be taken before any oil is put into the tank. Outside measurements should be taken when the tank is full of oil.

After one set of dimensions has been taken it is checked by taking a second set in exactly the same manner. The maximum permissible difference in these two sets of measurement should not be more than 1 in 10,000.

MEANING OF TERMS.

HEIGHT OF TANK.

The height of a tank for strapping purposes is the distance between the top of the bottom plate of the tank and the top of the horizontal leg of the top angle iron.

HORIZONTAL SEGMENT.

By the horizontal segment is meant the part of the tank shell, less the vertical lap, which encroaches on the area inclosed by a circle, the plane of which is parallel to the tank bottom and the diameter of

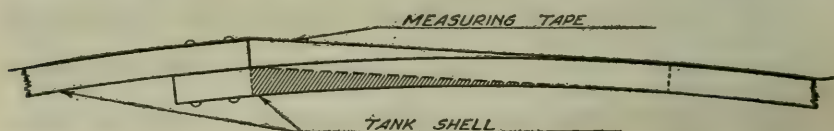


FIGURE 4.—Horizontal segment.

which is equal to the inside diameter of the tank. The hatched part in figure 4 shows the horizontal segment, which is approximately equal in area to the triangle made by the tape and the tank shell. The horizontal segment is not considered at all by many operators and by others is used only when very accurate results are required.

THICKNESS OF SHEETS.

The thicknesses of the sheets in the various rings can usually be most accurately and most easily determined from the specifications of the tank.

DEADWOOD.

The swing pipe and fittings and the water draw-offs in the bottom of the tank are usually omitted for the reason that they are always full of oil or water whenever a gage of the tank is taken, and the metal of which they are composed will at most displace only a small volume of liquid. To guard against the possibility of the swing pipe being empty or only partly filled when a gage of the tank is taken, some companies install on the shell of the tank about 2 feet from the

swing-pipe nozzle a 2-inch flange having its center line on approximately the same horizontal plane as the center line of the nozzle. A 2-inch pipe connection containing a valve is then placed between this flange and the nozzle, so that oil may be admitted from a point near the bottom of the tank into the bottom of the swing pipe whenever desired. Sand lines are also omitted. However, if there are steam coils in the tank, their volume must be deducted.

MANHOLE.

The dimensions of the manhole should be determined, as also its position, as the volume of oil that it contains must be added to the volume of the tank.

CORRUGATED-IRON AND WOODEN TANKS.

As regards corrugated-iron tanks, which are usually of small diameter, the circumference measurements are obtained with the tape lying in the valley of the corrugation. The depth of the corrugation and the distance between corrugations are noted.

In strapping wooden tanks with sloping sides, the thickness of the staves is taken at a number of places about the circumference, and an average thickness determined. The height is obtained by placing a gage rod inside the tank and measuring the vertical height to the top of the staves. The circumference strappings are taken at intervals of 2 feet, measured along the slope of the tank, beginning 6 inches from the bottom.

COMPUTING GAGE TABLES FOR TANKS.

From the circumference of each course the outside diameter of that course is computed, and by subtracting twice the thickness of the metal the inside diameter is determined, giving a value from which the gross area of the course is determined. From this is subtracted one-half the area of the vertical laps and the area of the horizontal segments, giving the net area (plus the deadwood). As the circumference is measured approximately in the center of the sheet, the net area value is considered to be a mean area for the course.

The volume in barrels per course, including the deadwood, is then calculated and the volume in barrels per one-fourth inch per course. Next the volume of the deadwood per course is determined and the volume of the deadwood per one-fourth inch per course. Then a table is prepared showing the quantity in barrels to be added for each one-fourth of an inch proceeding from the bottom of the tank upward. The construction of the gage table then resolves itself into the summation of the proper increments. If it were desired to have the gage table read to one-eighth inch the same method of computation would be pursued. In buying and selling crude oil it is customary to read the gage tape to the nearest one-eighth of an inch and interpolate in the table to find the correct volume.

Each step in the computations should be carefully checked. One-fourth inch totals must equal totals for courses calculated by subtracting the volume of the total deadwood in the course from the total volume of the course, and totals of courses must agree with a separate computation for the whole tank in which figures for total tank volume and total deadwood are used.

As a final check on the whole work a second man is required to make an independent calculation not quite so complete as the first but one that must check the total contents of each course and the total contents of the tank. Gage tables are made to read to the nearest one-hundredth of a barrel.

RESERVOIR MEASUREMENT AND TABLES.

For the convenience of the gager a small hatch is placed in the roof of the tank, usually near the head of the stairway. The gage tape is suspended through the hatch into the open tank. However, as regards reservoirs, it is customary to set what is known as a gage plate at some convenient place as close as practicable to the lowest point in the bottom of the reservoir and to take all measurements for depth of oil from this plate. It comprises a steel plate about $\frac{1}{2}$ inch thick and 3 feet square, which is set with foundation bolts and carefully leveled and grouted. This work is done as the part of the floor in that vicinity is being constructed so that it becomes an integral part of the lining. Some companies use a smaller gage plate and place on it a vertical pipe 4 to 10 inches in diameter of sufficient length to extend out through the roof of the reservoir. The walls of the pipe are perforated or slotted, and the top is fitted with a cap. Measurements for depth of oil are then taken through the pipe.

TESTING GAGE PLATE.

One of the first duties of the field or construction engineer in procuring the data necessary for the preparation of a gage table for the reservoir is to examine carefully the gage plate and determine whether all the foundation bolts are tight, and whether the plate has been properly grouted and has not sprung at any point, but is absolutely level over its entire surface. The following information should then be procured:

NECESSARY MEASUREMENTS IN TESTING GAGE PLATE.

1. The diameter at the toe of the inner slope.^a
2. The diameter at the top of the inner slope.^a
3. The elevation of the gage plate.
4. The elevation of a sufficient number of points on the bottom so that an accurate contour map may be plotted, the contour interval of which should be not more than one-fourth of an inch.

^a This measurement should be taken in as many places as possible and carefully checked.

5. The dimensions of all footings, posts, braces, and other deadwood as outlined for tank strappings.^a

4. The location and the size of the sump containing the swing pipes and water draw-off pipes.

COMPUTING GAGE TABLE.

From the elevation of the points on the bottom of the reservoir a contour map of one-fourth-inch interval is plotted and from this the gross content up to the gage plate is computed. To this is added the volume of the sump and from the sum is subtracted the volume of the deadwood up to the plane of the gage plate. The net amount thus obtained gives the content of the reservoir up to 0 feet 0 inches on the gage table.

If the gage table is to read to one-eighth of an inch, as is usually the case, the content is computed in a similar manner proceeding by eighths of an inch, up to the point where a horizontal plane will cut the side slopes of the reservoir. From this point to the top the volume is computed at one-eighth inch intervals, the reservoir being considered as a frustrum of a cone, deadwood being deducted as in the tank-table computations.

Gage tables are made to read to the nearest one-hundredth of a barrel. Volumes for fractions of an inch less than one-eighth are obtained by interpolation.

DEPRECIATION OF OIL IN STORAGE.

Table 7 shows comparative results of distillations of various fresh crude oils and oils from the same fields after being in storage for a period of years. The table indicates that practically every oil showed a considerable loss in the total proportion distilled from the stored liquid and that this loss reached its maximum at an end point of about 150° C.

Table 8 shows comparative results of tests on fresh and stored heavy California crude. The ultimate test showed that this low-gravity oil although having remained in storage for a period of six years seemingly had not lost in fuel value.

Although the samples of fresh and stored oil were taken from the same fields and as nearly as possible from the same wells, the fresh-oil samples were not, unfortunately, taken and analyzed at the time the oil was put in storage; on the contrary they were taken from the wells at the end of the storage period. The fact that the composition of oil produced by a given field often changes somewhat from time to time may account for seeming discrepancies in some of the figures.

^a As regards a reservoir, however, on account of the slope to the bottom, the exact location of the deadwood must also be determined.

TABLE 7.—Results of comparative distillation tests of fresh and of stored crudes.

[Apparatus, Bureau of Mines Hempel flask.]

CUSHING CRUDE.

[Stored crude in storage 2 years 5 months.]

Temperature.	Distillate of fresh crude.			Distillate of stored crude.			Fractions, per cent by volume.		Loss in total per cent distilled.	General data.		
	Frac-tions, per cent by vol-ume.	Total per cent dis-tilled.	Grav-ity.	Frac-tions, per cent by vol-ume.	Total per cent dis-tilled.	Grav-ity.	Loss.	Gain.		Item.	Fresh crude.	Stored crude.
° C.	° B.			° B.			6.0				40.9	38.0.
Up to 75.....	6.5	6.5	83.0	0.5	0.5	.....	.....	.....	6.0	Gravity, ° B.....	Below 75.....	Below 75.
75 to 100.....	4.8	11.3	65.5	4.6	5.1	66.0	.2	.....	6.2	Flash point, ° F.....	Below 75.....	77.
100 to 125.....	7.2	18.5	60.0	6.2	11.3	60.3	1.0	.....	7.2	Fire point, ° F.....	Below 75.....	None.
125 to 150.....	6.4	24.9	55.0	8.0	19.3	55.5	.....	1.6	5.4	Sand.....	Appreciable amount.....	None.
150 to 175.....	6.3	31.2	50.8	6.9	26.2	51.0	.....	.6	3.0	Water.....	None.....	1.5.
175 to 200.....	6.0	37.2	47.0	5.3	31.5	47.0	.7	.....	3.7	Viscosity at 20° C., ° Engler.....	1.4.....	Liquid.
200 to 225.....	5.5	42.7	44.0	6.8	38.3	43.8	.....	1.3	4.5	Cold test at 0° C.....	Liquid.....	
225 to 250.....	5.7	48.4	41.0	6.2	44.5	40.5	.....	.5	3.9			
250 to 275.....	5.6	54.0	38.5	6.3	50.8	38.3	.....	.7	3.2			
275 to 300.....	6.5	60.5	36.5	6.7	57.5	36.5	.....	.2	3.0			

GLENN CRUDE.

[Stored crude in storage 7 years 3 months.]

Up to 75.	2.7	2.7	79.0	.....	0.0	.....	2.7	.....	2.7	Gravity, ° B.....	Flash point, ° F.....	32.9.....	32.7.
75 to 100.	2.2	4.9	63.3	1.8	1.8	.....	.....	.....	3.1	Below 72.....	Below 72.....	86.	
100 to 125.	4.3	9.2	59.0	2.4	4.2	.....	1.9	.....	5.0	Below 72.....	Below 72.....	127.	
125 to 150.	4.2	13.4	54.0	6.1	10.3	55.0	.....	.....	3.1	Sand.....	None.....	None.	
150 to 175.	4.9	18.3	50.0	6.0	16.3	50.2	.....	.....	1.1	Water.....	None.....	None.	
175 to 200.	4.2	22.5	45.8	4.7	21.0	46.5	.....	.....	2.0	Viscosity at 20° C., ° Engler.....	2.2.....	2.1.	
200 to 225.	4.8	27.3	42.5	6.3	27.3	43.5	.....	.....	1.5	Cold test at 0° C.....	Liquid.....	Liquid.	
225 to 250.	5.8	33.1	40.0	7.0	34.3	40.5	.....	.....	1.2				
250 to 275.	5.1	38.2	38.2	7.2	41.5	37.5	.....	.....	2.1				
275 to 300.	6.4	44.6	36.3	7.8	49.3	36.5	.....	.....	.....				

TABLE 7.—*Results of comparative distillation tests of fresh and of stored crudes—Continued.*

[Apparatus, Bureau of Mines Hempel flask.]

"OKMULGEE COUNTY," OKLA., CRUDE.

[Stored crude in storage 7 years 4 months.]

Temperature.	Distillate of fresh crude.			Distillate of stored crude.			Fractions, per cent by volume.		Loss in total per cent distilled.	General data.			
	Fractions, per cent by vol- ume.	Total per cent dis- tilled.	Grav- ity.	° B.	Total per cent by dis- tilled.	Grav- ity.	° B.	Loss.		Gain.	Item.	Fresh crude.	Stored crude.
° C.													
Up to 75.....	1.0	1.0			0.0			1.0		1.0	Gravity, °B.....	35.0.....	32.4.
75 to 100.....	1.5	2.5			0.0			1.5		2.5	Flash point, °F.....	Below 72.....	120.
100 to 125.....	3.0	5.5	60.0	1.5	1.5			1.5		4.0	Fire point, °F.....	111.....	165.
125 to 150.....	3.0	8.5	55.0	2.9	4.4		54.8	.1		4.1	Sand.....	None.....	None.
150 to 175.....	3.7	12.2	51.2	3.6	8.0		51.0	.8		4.2	Water.....	None.....	None.
175 to 200.....	3.8	16.0	48.3	3.0	11.0		48.0			5.0	Viscosity at 20° C., ° Engler.....	2.5.....	4.3.
200 to 225.....	4.3	20.3	45.3	4.7	15.7		45.0		0.4	4.6	Cold test at 0° C.....	Liquid.....	Slightly viscous.
225 to 250.....	5.4	25.7	42.5	5.8	21.5		42.0		.4	4.2			
250 to 275.....	6.5	32.2	39.4	6.5	28.0		39.4			4.2			
275 to 300.....	6.5	38.7	38.8	10.5	38.5		38.7		4.0	.2			

TABLE 8.—Results of comparative tests of fresh and of stored California crude.

DISTILLATION TESTS.

Temperature.	Fresh crude.			Crude stored for 6 years.			Fractions, per cent by weight.		Loss in total proportion distilled.
	Fractions, per cent by weight.	Total per cent distilled.	Gravity.	Fractions, per cent by weight.	Total per cent distilled.	Gravity.	Loss.	Gain.	
°C.			°B.			°B.			Per cent.
Up to 175..	1.0	1.0	38.2	0.7	0.7	37.0	0.3	.....	0.3
175 to 200..	1.4	2.4		1.1	1.8		.3	.....	.6
200 to 225..	2.1	4.5	31.8	2.1	3.9	31.8	.0	.....	.6
225 to 250..	3.4	7.9		3.3	7.2		.1	.....	.7
250 to 275..	5.4	13.3	30.8	4.8	12.0	29.8	.6	.....	1.3

ULTIMATE TEST.

OIL.	Gravity at 60° F.	Viscosity 20° C.	Heating value per pound.	Water.	Sulphur.	Sand.	Flash point, Pensky-Martens tester, closed.	Burning point, Pensky-Martens tester, opened.	Remarks.
	°B.	°Engler.	B. t. u.	Per ct.	Per ct.	Per ct.	°F.	°F.	
Fresh.....	14.3	625	18,493	0.6	0.79	None..	188	325	Very viscous at 32° F.
Stored 6 years...	14.0	737	18,522	.6	.86	..do...	214	318	Do.

RÉSUMÉ.

In summing up it is well to repeat that the best all-around container in use at the present time for storing oil is the all-steel tank of gas-tight construction.

Tanks that are used for the accumulation of fresh oils from the well should invariably be of this construction, and as a rule it will probably pay to equip them with water-seal tops, if not also with some form of tile encasing or lagging.

Other devices for lessening the temperature of the oil in the tanks that can be cheaply applied and economically maintained, such as sprinkling with water in hot weather and painting the tanks white, are worth while.

To store gasoline or light distillate in tanks that have not tight tops is the height of folly, and it is poor judgment not to use also some type of cooling device.

Large concrete-lined reservoirs, as at present constructed, should not be used for the storage of fresh oils or of light oils.

It will pay to line a reservoir with concrete even though heavy oil only is to be stored.

In most cases it would probably also pay to put a concrete roof on the reservoir and cover it with earth—at least such a type of structure is worthy of consideration, no matter what the gravity of the oils to be handled.

Concrete, if properly proportioned, mixed, poured, tamped, and floated, can be made impervious to heavy oils without the addition of so-called "oil-proofing" compounds.

Contrary to popular engineering opinion, expansion joints are not necessary in properly constructed concrete linings for oil reservoirs in temperate climates, and no injury will result to the linings from their omission if the reservoirs be kept reasonably full of oil, or if, when the tanks are not in use, they are kept partly filled with water.

If crude can be refined at any profit, it should be put through the refinery as soon as possible after it is taken from the wells. If refining will not pay, the period of storage should be as short as possible because, so far as the oil is concerned, at best, each day of storage will entail a loss.

ACKNOWLEDGMENTS.

Acknowledgments for information contained in this publication are due the following persons:

Forrest M. Towl, president, Eureka Pipe Line Co.; C. R. Ewing, superintendent, Standard Oil Co., at Baltimore, Md.; J. E. O'Neill, president, W. S. Fitzpatrick, and N. K. Moody, vice presidents, and J. L. Havice, comptroller, Prairie Oil & Gas Co.; A. M. Donoghue, superintendent of pipe lines, Texas Co.; E. R. Brown, general manager, Magnolia Petroleum Co.; John W. Tryon, manager, Gulf Refining Co., Port Arthur, Tex.; H. M. Storey, secretary, L. D. Dimm, manager of refineries, and H. H. Hall, engineer, of the Standard Oil Co. of California; A. D'Heur, manager, M. E. Lombardi, superintendent of construction, H. B. Truett, chief engineer, W. E. Perdew, chemist, and Earl Derby, field superintendent, fuel-oil department, Southern Pacific R.R.; E. B. Partridge, manager, and G. B. Maloney, engineer, Associated Pipe Line Co.; R. P. Schwerin, manager, F. B. Henderson, assistant general manager, A. F. L. Bell, chief engineer, and L. D. Jurs and W. E. White, assistant engineers, Associated Oil Co.; E. W. Clark, manager, Ralph J. Reed, chief engineer, and E. I. Dyer, manager of refineries, Union Oil Co.; N. W. Thompson, chief engineer, Simplex Refining Co.; F. A. Milliff, F. A. Milliff Refining Co.; E. D. Cole, associate member, American Society Civil Engineers; O. D. Donnell, Ohio Oil Co.; W. J. Higgins, Producers & Refiners Pipe Line Co.; J. E. Freeman, engineer, Portland Cement Association; and E. W. Dean, organic chemist, A. R. Elliott, assistant engineer, and A. A. Hammer, oil and gas inspector, of the Bureau of Mines.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 120. Extraction of gasoline from natural gas by absorption methods, by G. A. Burrell, P. M. Biddison, and G. G. Oberfell. 1917. 71 pp., 2 pls., 15 figs.

BULLETIN 134. The use of mud-laden fluid in oil and gas wells, by J. O. Lewis and W. F. McMurray. 1916. 86 pp., 3 pls., 18 figs.

BULLETIN 148. Methods for increasing the recovery of oil from wells, by J. O. Lewis. In press.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas, and methods for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 45. Waste of oil and gas in the Mid-Continent fields, by R. S. Blatchley. 1914. 54 pp., 2 pls., 15 figs.

TECHNICAL PAPER 49. The flash point of oils, methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.

TECHNICAL PAPER 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

TECHNICAL PAPER 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp., 5 figs.

TECHNICAL PAPER 70. Methods of oil recovery in California, by Ralph Arnold and V. R. Garfias. 1914. 57 pp., 7 figs.

TECHNICAL PAPER 72. Problems of the petroleum industry, results of conferences at Pittsburgh, Pa., August 1 and September 10, 1913, by I. C. Allen. 1914. 20 pp.

TECHNICAL PAPER 79. Electric lights for oil and gas wells, by H. H. Clark. 1914. 8 pp.

TECHNICAL PAPER 87. Methods of testing natural gas for gasoline content, by G. A. Burrell and G. W. Jones. 1916. 26 pp., 7 figs.

TECHNICAL PAPER 104. Analysis of natural gas and illuminating gas by fractional distillation in a vacuum at low temperatures and pressures, by G. A. Burrell, F. M. Seibert, and I. W. Robertson. 1915. 41 pp., 7 figs.

TECHNICAL PAPER 117. Quantity of gasoline necessary to produce explosive vapors in sewers, by G. A. Burrell and H. T. Boyd. 1916. 18 pp., 4 figs.

TECHNICAL PAPER 127. Hazards in handling gasoline, by G. A. Burrell. 1915. 12 pp.

TECHNICAL PAPER 130. Underground wastes in oil and gas fields and methods of prevention, by W. F. McMurray and J. O. Lewis. 1916. 28 pp., 1 pl., 8 figs.

TECHNICAL PAPER 131. The compressibility of natural gas at high pressures, by G. A. Burrell and I. W. Robertson. 1916. 11 pp., 2 figs.

TECHNICAL PAPER 161. Construction and operation of a single-tube cracking furnace for making gasoline, by C. P. Bowie. 1916. 16 pp., 10 pls.

TECHNICAL PAPER 163. Physical and chemical properties of gasolines sold throughout the United States during the calendar year 1915, by W. F. Rittman, W. A. Jacobs, and E. W. Dean. 1916. 45 pp., 4 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPER-INTENDENT OF DOCUMENTS.

BULLETIN 19. Physical and chemical properties of the petroleum of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs. 10 cents.

BULLETIN 32. Commercial deductions from comparisons of gasoline and alcohol tests on internal-combustion engines, by R. M. Strong. 38 pp. 5 cents.

BULLETIN 43. Comparative fuel values of gasoline and denatured alcohol in internal-combustion engines, by R. M. Strong and Lauson Stone. 1912. 243 pp., 3 pls., 32 figs. 20 cents.

BULLETIN 65. Oil and gas wells through workable coal beds: papers and discussions, by G. S. Rice, O. P. Hood, and others. 1913. 101 pp., 1 pl., 11 figs. 10 cents.

BULLETIN 88. The condensation of gasoline from natural gas, by G. A. Burrell, F. M. Seibert, and G. G. Oberfell. 1915. 106 pp., 6 pls., 18 figs. 15 cents.

BULLETIN 114. Manufacture of gasoline and benzene-toluene from petroleum and other hydrocarbons, by W. F. Rittman, C. B. Dutton, and E. W. Dean, with a bibliography compiled by M. S. Howard. 1916. 268 pp., 9 pls., 45 figs. 35 cents.

BULLETIN 125. The analytical distillation of petroleum, by W. F. Rittman and E. W. Dean. 1916. 79 pp., 1 pl., 16 figs. 15 cents.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp. 5 cents.

TECHNICAL PAPER 10. Liquefied products of natural gas, their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp. 5 cents.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs. 5 cents.

TECHNICAL PAPER 26. Methods for the determination of the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1912. 13 pp., 1 fig. 5 cents.

TECHNICAL PAPER 36. The preparation of specifications for petroleum products, by I. C. Allen. 1913. 12 pp. 5 cents.

TECHNICAL PAPER 51. Possible causes of the decline of oil wells, and suggested methods of prolonging yield, by L. G. Huntley. 1913. 32 pp., 9 figs. 5 cents.

TECHNICAL PAPER 53. Proposed regulations for the drilling of oil and gas wells, with comments thereon, by O. P. Hood and A. G. Heggem. 1913. 28 pp., 2 figs. 5 cents.

TECHNICAL PAPER 57. A preliminary report on the utilization of petroleum and natural gas in Wyoming, by W. R. Calvert, with a discussion of the suitability of natural gas for making gasoline, by G. A. Burrell. 1913. 23 pp. 5 cents.

TECHNICAL PAPER 74. Physical and chemical properties of the petroleum of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Matthews. 1914. 38 pp., 1 fig. 5 cents.

TECHNICAL PAPER 109. Composition of the natural gas used in 25 cities, with a discussion of the properties of natural gas, by G. A. Burrell and G. G. Oberfell. 1915. 22 pp. 5 cents.

TECHNICAL PAPER 115. Inflammability of mixtures of gasoline vapor and air, by G. A. Burrell and H. T. Boyd. 1915. 18 pp., 2 figs. 5 cents.

TECHNICAL PAPER 120. A bibliography of the chemistry of gas manufacture, by W. F. Rittman and M. C. Whittaker, compiled and arranged by M. S. Howard. 1915. 30 pp. 5 cents.

INDEX.

	Page.		Page.
Aluminum paint for coating of tanks	58	E.	
American Society for Testing Materials, specifications for steel by	9-11	Ewing, C. R., acknowledgments to	70
B.		Expansion joints for reservoirs	31, 70
Bakersfield, Cal., costs of reservoirs at	35	Explosion doors for tanks, construction of ..	18
Bartlesville field, crude oil from, distillation tests of	67	details of, view of	14
Bell, A. F. L., acknowledgments to	70	specifications for	1
Brown, E. R., acknowledgments to	70	view of	18
Bureau of Mines, investigations of	3	Fires at oil tanks, causes of	19, 20
C.		prevention of explosions during	18
California, concrete-lined reservoirs in	20	F.	
crude oil from, evaporation losses of	50	Fitzpatrick, W. S., acknowledgments to	70
results of distillation tests of	69	Fort Smith, Ark., reinforced-concrete tanks at ..	56
storage losses of oil in	42-47	Fort Worth, Tex., losses of stored oil at	40
Caney, Kans., wooden-roof tank at, loss of oil from	39	Freeman, J. E., acknowledgments to	70
Clark, E. W., acknowledgments to	70	Fuller, W. B., cited	31
Cole, E. D., acknowledgments to	70	G.	
Concrete as lining for reservoir, details of, view of	26	Gage plate, description of	64
pouring of	28	testing of	64
proper mixing and tamping of	30, 31	Gage tables for tanks, method of computing ..	63-65
reduction of seepage losses by	37	Gasometer, description of	54
specifications for	27, 28	purpose of	54
sprinkling of	28, 29	view of	18
coatings for, tests of	33	Glenn field, crude oil from, results of distillation ..	66
permeability of, tests of	33, 34	Grades for tanks, factors governing	4
roofs, merits of, tests of	3, 30	Grade stakes, method of cutting, view of	4
Costs of tanks	20, 55	specifications for	22
of reservoirs, details of	35, 36	H.	
Crude oil, deterioration of, in storage	65	Hammer, A. A., acknowledgments to	70
fresh, comparative distillation tests of ..	66-69	Higgins, W. J., acknowledgments to	70
losses in storage of	37, 48	Henderson, F. B., acknowledgments to	70
stored, comparative distillation tests of, results of ..	66-69	Hall, H. H., acknowledgments to	70
See also States and oil fields named.		Havice, J. L., acknowledgments to	70
Cushing field, crude oil from, results of distillation from	66	Horizontal segment of tank, definition of ..	62
wooden-roof tanks in, losses of oil from ..	40	figure showing	62
D.		I.	
D'Heur, A., acknowledgments to	70	Illinois, crude oil from, evaporation losses of ..	41, 50
Deadwood of tank, measurement of	60-63	J.	
Dean, E. W., acknowledgments to	70	Jenks, Okla., wooden-roof tank at, loss of oil from ..	39
Derby, Earl., acknowledgments to	70	Jurs, L. D., acknowledgments to	70
Dimm, L. D., acknowledgments to	70	K.	
Donnell, O. D., acknowledgments to	70	Kansas, crude oil from, evaporation losses of ..	50
Donoghue, A. M., acknowledgments to	70	Kern River field, Cal., storage losses of oil in ..	47
Drains for roof of reservoir, specifications for ..	26	L.	
Dyer, E. I., acknowledgments to	70	Ladders for reservoir, construction of	25
E.		Lombardi, M. E., acknowledgments to	70
Earthen reservoirs, losses of oil in	37	Lost Hills field, Cal., storage losses of oil in ..	42-44
Elliott, A. R., acknowledgments to	70	Louisiana, crude oil from, evaporation losses of	41, 50
Embankment for reservoir, method of building ..	29, 30	M.	
oiling of	30	Maloney, G. B., acknowledgments to	70
view of	30	Manhole of tank, measurement of, need of ..	63
Evaporation, losses of oil by	37, 40, 41	specifications for	7
errors in computing	51	Midway field, Cal., storage losses of oil in ..	45-4
factors governing	42-47, 58	Millif, F. A., acknowledgments to	70
relation of, to gravity	48	Moody, N. K., acknowledgments to	70
theory of	51		

	N.	Page.		Page.
Neodesha, Kans., wooden-roof tank at, loss of oil from.....		39	Steel, inspection of, requirements for.....	14
Nowata County, Okla., crude oil from, distillation tests of.....		67	permissible variations in.....	11
	O.		rivet, standard specifications for.....	9-11
Oklahoma, crude oil from, evaporation losses of.....		41, 50	structural, standard specifications for.....	9-11
O'Neill, J. E., acknowledgments to.....		70	tension tests of, specimen for, figure showing.....	10, 11
Osage field, crude oil from, distillation tests of.....		67	Steel plates for tanks, size of.....	16
	P.		thickness of, specifications for.....	6
Paint for tank, color of, effect on evaporation losses.....		58	weight of, permissible variations in.....	12, 13
Partridge, E. B., acknowledgments to.....		70	Steel tank, details of, view of.....	4, 6
Pennsylvania, crude oil from, evaporation losses of.....		40, 50	durability of.....	36
Perdew, W. E., acknowledgments to.....		70	losses of oil from.....	40, 50
investigations of permeability of concrete.....		33, 34	merits of.....	69
Pittsburgh, Pa., steel tanks at, losses of oil from.....		40	sizes of.....	4
	R.		specifications for.....	5-14
Ramona, Okla., wooden-roof tank at, loss of oil from.....		39	Storage farms, description of.....	3
Reed, R. J., acknowledgments to.....		70	view of.....	4
on expansion joints for reservoirs.....		31	Storey, H. M., acknowledgments to.....	70
Reservoirs, concrete-lined, costs of.....		35, 36	Sump for reservoir, details of, view of.....	24
dimensions of.....		21	Swing pipe for reservoir, details of, view of.....	24
durability of.....		36	for tanks, construction of.....	16
evaporation of oil from.....		50	plan of, view of.....	10
material for, inspection of.....		21	specifications for.....	7
plan of, view of.....		22	swivel joints for, construction of.....	17
reinforcing material for, view of.....		28	plan of, view of.....	10
specifications for.....		21-29		T.
sump and swing pipe for, details of, view of.....		24	Tank farms. <i>See</i> Storage farms.	
construction of embankment for.....		23, 24	Tank, burying of, objections to.....	54
earthen, objections to.....		20	construction of, view of.....	4
site for, factors governing.....		29	cooling of, sprinkler for, view of.....	52
slope of, trimming of, views of.....		30	erection of.....	4
temperature in, variations of.....		32	levees around, advantage of.....	3
unlined, evaporation of oil from.....		50	painting of.....	58
volume of, computing of.....		59	measurement of, method for.....	60, 61
Roof, reservoir, details of, view of.....		28	reinforced concrete, advantages of.....	55
specifications for.....		24, 25	construction of.....	54, 55
sheathed, view of.....		32	cost of.....	55
tank, caking of, discussion of.....		15, 16	durability of.....	55, 56
construction of, view showing.....		30	users of, list of.....	57
specifications for.....		7	reinforcement for, view showing.....	30
steel, plan of, view of.....		8	volume of, computing of.....	59
wooden, construction of.....		19	with water-seal top, view of.....	52
covering for.....		19	<i>See also</i> Steel tanks; Wooden-roof tanks.	
durability of.....		36, 37	Tank bottom, construction of, precautions in view of.....	4
objections to.....		19, 30	testing of, specifications for.....	6
Roofing gravel, specifications for.....		26	wetting of, view of.....	18
Roofing materials. <i>See</i> Concrete; Steel; Wood.			Texas, crude oil from, evaporation losses of.....	41, 50
Roofing paper, specifications for.....		26	Thompson, N. W., acknowledgments to.....	70
	S.		Thompson, S. E., cited.....	31
St. Helena, Cal., reinforced concrete tank at.....		56	Tile casing for tanks, purpose of.....	54
San Antonio, Tex., reinforced concrete tank at.....		55	view of.....	18, 54
Sand-line construction of tanks, advantages of.....		14, 15	Tin plating of tanks, effect of, on evaporation losses.....	58
description of.....		15	Towl, F. M., acknowledgments to.....	70
Schwerin, R. P., acknowledgments to.....		70	Truett, H. B., acknowledgments to.....	70
Seepage, loss of oil by.....		37	cited.....	33
Sheathing for roof, specifications for.....		25	Tryon, J. W., acknowledgments to.....	70
Sheet-iron roofs.....		19, 53	Tulsa, Okla., reinforced concrete tank at.....	56
Shell of tank, specifications for.....		7		V.
Specifications for concrete-lined reservoirs.....		21-29	Valve, vacuum relief, construction of.....	19
steel tanks.....		5-14	view of.....	18
Sprinkler for tank, description of.....		53, 54	Ventilator for reservoir, construction of.....	25
view of.....		52		W.
Stairway for reservoir, construction of.....		25	Water-seal tops for tank, advantage of.....	52, 69
for tank, construction of.....		17	description of.....	52
details of, view of.....		14, 18	evaporation losses from.....	53
specifications for.....		7	view of.....	52
			White, W. E., acknowledgments to.....	70
			Wind stresses, resistance to.....	14, 15
			Wood roofs, use of.....	3
			<i>See also</i> Roofs.	
			stairs, objections to.....	17
			Wooden-roof tanks, losses of oil from.....	39,
				40, 41-47, 50

